

O P E R A T I O N H I D E O U T

Preliminary Report

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ABSTRACT

In order to determine the effects of prolonged exposure to 1.5 per cent carbon dioxide, twenty-three human volunteers were placed aboard a partially activated fleet type submarine for a period of two months and were exposed to that percentage of carbon dioxide during six weeks of this period. Prior to, during, and after the exposure period, measurements of physiological functions and psychomotor performance were made.

Certain physiological changes occurred which indicated a definite response to this concentration of carbon dioxide. These changes were: a decrease in the respiratory response to carbon dioxide, and a consistent decrease in eosinophil count. There was a slight fall in serum pH consistent with a very mild respiratory acidosis and the urinary excretion of bicarbonate rose to levels significantly greater than normal in the last four weeks of exposure. Measurements of psychomotor performance, including simple motor responses, sensory discrimination, complex motor coordination, and alertness, revealed no significant decrement in these functions.

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INTRODUCTION

In August 1951 the Chief of the Bureau of Ships, in a letter to the Chief of the Bureau of Medicine and Surgery, stated that in order to carry out the operational requirements as specified in the Navy Research and Development Plan PO12401 and SW 01401 and in order to meet the requirements for 55 day continuous submergence as specified in the circular of requirements for building the SSN, designs of equipment to control the levels of oxygen and carbon dioxide concentrations inside a submarine were being prepared. Since the designs would depend to a great degree on the permissible limits of oxygen and carbon dioxide, and since previous experience had been restricted to relatively short periods, the Bureau of Medicine and Surgery was requested to specify the limits that are accepted physiologically over long periods of exposure.

In May 1952, the Officer in Charge, NMRL, in a letter to the Chief of Naval Operations, stated that investigations on the maximum allowable concentrations of CO₂ for prolonged exposure had reached the stage where it would be necessary to expose a number of human subjects in a completely closed chamber for a period of approximately three months. Since no completely satisfactory chamber existed in any navy medical laboratory it was proposed that a submarine would be ideal for this purpose, in view of the fact that facilities for such a project are inherent in a submarine. It was therefore requested that a submarine in the Atlantic Reserve Fleet be made available for the project. Following appropriate correspondence the USS HADDOCK (SS231) was nominated for the project, with an availability from 5 January 1953 to 20 March 1953.

The physiological effects of various concentrations of CO₂ had been under study at this laboratory for some time. Work had proceeded in an orderly scientific manner testing the effect of various concentrations of CO₂ on the human being. Correspondence from the Chief, Bureau of Ships to the Secretary of the Navy stated that in the design of the USS NAUTILUS (SSN571) and USS SEA WOLF (SSN573) the Bureau of Ships must make provision for insuring a healthful atmosphere for prolonged submergence. One of the problems involved in provision of a satisfactory means of removal of carbon dioxide in the atmosphere of these boats for an indefinite period. To fulfill this need, a regenerative type carbon dioxide scrubber had been developed. Laboratory models of this equipment had demonstrated that a maximum concentration of 1.5% carbon dioxide can be maintained in a submarine. An equipment of this type was contemplated for the nuclear powered submarines. Information was not available, however, to insure that a concentration of 1.5% carbon dioxide would permit efficient human performance beyond seventy-two hours exposure. The Bureau of Ships required early information regarding maximum allowable carbon dioxide concentrations so that proper provisions could be made to permit early and full evaluation of nuclear powered submarines. Therefore, in the experimental design for this test the carbon dioxide concentration was maintained at 1.5%.

METHODS AND PROCEDURE

The volunteer group underwent comprehensive physiological, psychological and sociometric tests in December 1952 and early January 1953 to collect data prior to the actual test phase. In addition they received a brief psychiatric interview. From the information gained from this study various volunteers were eliminated for medical or psychological reasons.

Twenty-two enlisted men and one medical officer were selected for the actual test phase within the submarine.

At 0930 hours on 19 January 1953 the twenty-three human volunteers went aboard USS HADDOCK (SS231).

For the purposes of this test, the forward engine room and all spaces forward to it were activated. The forward escape trunk was used as the primary air lock and the forward torpedo room as the secondary air lock. The actual test compartments were the forward battery, control room and after battery.

The first nine days within the submarine, the volunteers breathed atmospheric air. During this time the entire battery of planned tests were completed to furnish the control or baseline data for the project. At 2000 hours on 27 January 1953 the submarine hull ventilation openings were shut, thus sealing the atmosphere within the submarine from contact with weather air. At this time the CO₂ concentration was built up to 1.5%. Meanwhile the atmosphere within the submarine was controlled by electronic devices and regulated so that the CO₂ concentration was maintained at 1.5% and the oxygen concentration at 20.5%.

The CO₂ concentration of 1.5% was maintained within the submarine atmosphere for a period of 42 days. Oxygen was supplied from a modified Helium-Oxygen diving manifold that was located nearby. Excess amounts of CO₂ that accumulated within the test compartments were removed by a CO₂ removal device (the Northwestern caustic scrubber) located in the forward torpedo room of the submarine.

At 2000 hours on 10 March 1953 the hull ventilation openings on the submarine were opened, establishing communication between the interior of the submarine and weather air. The volunteers breathed atmospheric air the last nine days of the test while final studies were being completed within the submarine. On 19 March 1953 at 1400 hours the 23 volunteers emerged after 60 days incarceration within the compartments of the USS HADDOCK.

After leaving the submarine the volunteer group underwent extensive physiological, psychological and sociometric tests. These tests were completed in the latter part of April 1953.

Therefore there were five phases of testing:

1. The initial laboratory testing (35 days).
2. Control period on atmospheric air within the submarine (9 days).
3. Under 1.5% CO₂ within the submarine (42 days).
4. Control period on atmospheric air within the submarine (9 days).
5. Final laboratory testing (35 days).

RESULTS

The conclusions presented below represent careful analysis of the data collected as of this date. They are by no means to be construed as final opinions in as much as the data will require much more detailed, exhaustive and critical analysis. However, these results will produce an over-all summary of the main investigative procedures. The many facets of the individual tests and studies will be presented in future publications as rapidly as proper and careful review and interpretation of the data will permit.

A. Physiological Aspects:

1. Basic data. Taking of pulse rate, weight, oral temperature, and systolic and diastolic blood pressure under basal conditions in the morning right after awakening are considered to be very valuable in indicating any significant change in circulation and metabolism. As shown in Figure 1, no significant changes were found during prolonged exposure to 1.5% CO₂.

2. Diurnal variations. Measurements of diurnal variations of blood pressure, pulse rate, oral temperature, total leucocytes, total eosinophils, and total lymphocytes were made on a group of six subjects for two days in a row (a) prior to CO₂ exposure on the boat, (b) during the first two weeks of CO₂ exposure, (c) during the fifth and sixth weeks of CO₂ exposure, (d) during the first two weeks post exposure to CO₂, and (e) three to four weeks post exposure to CO₂. Changes in diurnal cycles of these functions suggest a deep change in physiological adaptation to the environment. The diurnal pattern of blood pressure, temperature and pulse rate showed no systematic change during exposure to CO₂, although the pulse rate tended to be slightly higher than during the control period. Similarly, no change occurred in the pattern of lymphocytes, leucocytes and eosinophils, however, were at a lower level at the end of CO₂ exposure and for two weeks thereafter than during the control period and the first two weeks of the exposure to CO₂. In general, no systematic, consistent change in the diurnal cycles could be detected, especially no reversion: cycles were not reversed.

3. Respiration. Alveolar CO₂ tensions, respiratory minute volume, oxygen consumption, and CO₂ excretion were measured throughout the experiment on two groups of 10 subjects each. Data are presented in Figure 2. It can be seen that the two groups vary from each other in their responses to CO₂. This is due to the fact that these groups had different numbers of subjects who were more sensitive to CO₂. In a

final evaluation of these data, subjects with high ventilatory response and those with low ventilatory response to CO_2 should be grouped together. The following presentation of the data represent only the very preliminary evaluation.

a. Alveolar CO_2 tension. Alveolar CO_2 tension rises, as expected, during exposure to 1.5%. It is noteworthy that it takes two days before a significant increase in alveolar CO_2 tension is reached. Note, secondly, that following transition to air, the alveolar CO_2 tension remains elevated above the initial level throughout the control period. This is in contrast to the usual finding of an undershooting of alveolar CO_2 tension below the initial alveolar CO_2 level in acute exposure to 1.5%. The prolonged exposure apparently has the effect of eliminating the usual transitory response to CO_2 . This finding has to be discussed in detail in connection with other experiments.

b. Ventilation was increased throughout the CO_2 exposure to 1.5%, as was expected, and dropped and returned to initial levels within the first three days post exposure. The final increase, at the end of the control period, may be due to external reasons: alcohol consumption on liberty, and so forth.

c. Oxygen consumption. Oxygen consumption seems to be somewhat increased throughout the first part of the CO_2 exposure up to 14 days and apparently returns to the initial level in the latter part of CO_2 exposure. Following transition to air, oxygen consumption remains for the first three or four days at the same level.

d. CO_2 excretion. CO_2 excretion drops continuously up to the fifth to the eighth day, respectively, of CO_2 exposure, and then shows an increase for the following two weeks. During the last two weeks of CO_2 exposure, CO_2 excretion drops again, but on transition to air returns promptly to initial levels. These three phases of CO_2 excretion during the CO_2 exposure parallel the CO_2 excretion of the urine. The initial

drop is to be expected, because of the well-known fact that breathing gas with increased CO_2 consumption will result in a degree of uptake of excess CO_2 by body alkali in an endeavor to maintain a constant pH. Until a new equilibrium is reached between the increased CO_2 tension and the CO_2 content of the body buffers, the amount of CO_2 in the expired air must be less than the sum of CO_2 normally expired by breathing air and the CO_2 added in the experiment. The low point of CO_2 excretion at the 5th - 8th day represents the point, apparently, at which the buffers are saturated. A new equilibrium begins to develop during the following two weeks between the increased CO_2 tension and the increased CO_2 content of the blood buffers. A second drop during the end of CO_2 exposure can as yet not be explained. The respiratory gas ratio follows essentially the curve of CO_2 excretion.

e. CO_2 sensitivity tests. CO_2 sensitivity tests were carried out prior to the CO_2 exposure, at the end of CO_2 exposure, and three weeks post CO_2 exposure. They consisted of breathing of 1.5% CO_2 and 5% CO_2 over a period of 15 minutes. Pre- and post-exposure to CO_2 were periods on air of equal length. Table A gives the result of the ventilatory response to 5% CO_2 . There was a significant drop at the end of CO_2 exposure, and the variations were much less than in the tests prior to exposure to CO_2 . Post exposure to CO_2 , ventilatory response increased but still did not reach the initial level; it was still significantly less than the initial response. These CO_2 sensitivity tests demonstrate that the sensitivity of the respiratory center to CO_2 is significantly decreased at the end of six weeks' exposure to 1.5% CO_2 .

4. Hematology. The following data were taken: red blood count, white blood count, hemoglobin, hematocrit, reticulocyte counts, and differential. Times: (a) prior to CO_2 exposure, (2) after four weeks of CO_2 exposure, (3) after six weeks of CO_2 exposure, (4) one week after and (5) four weeks after the end of CO_2 exposure. Red blood count did not change; neither did white blood count nor hemoglobin.

Table "A" Ventilatory Responses to 5% CO₂ prior to (I), at the end of 6 to 7 weeks exposure to 1.5% CO₂ (II), and Post Exposure to CO₂ (III)

	I	II	III
	Prior to exposure	At end of exposure	Post exposure
Number of subjects	20	20	20
Respiratory minute Volume S.P.D. l/Min.	18.8 ± 6.27	12.6 ± 1.91	15.39 ± 4.32
P		.002	
P			.03
P			.005

The eosinophil count dropped consistently from control values of 143 per cubic millimeter to reach the lowest value of 49 per cubic mm. eight days after the end of exposure to CO₂. Four weeks post exposure, eosinophils still had not reached the initial level.

The total lymphocytes did not change significantly throughout the CO₂ exposure. Eight days after the end of CO₂ exposure a remarkably high value was found. Four weeks post exposure the lymphocyte counts returned to the initial level.

The total neutrophils dropped slightly throughout CO₂ exposure, reaching a very low value eight days post exposure, but came back to initial level after four weeks post exposure.

The reticulocyte counts did not show any significant changes throughout the experiment.

Summary: Prolonged exposure to 1.5% does not seem to influence the erythropoietic system. However, the consistent downward trend of the eosinophils throughout the CO₂ exposure and eight days following the end of CO₂ exposure indicates an increasing stress on the adrenal system. The leucopoietic system seems more affected as shown in the consistent decrease of total neutrophils throughout exposure to CO₂ and eight days post exposure.

5. Electroencephalographic Studies: Repeated EEG's were taken from the subjects prior to and during CO₂ exposure and post exposure to obtain information as to (a) change in frequency and amplitudes, (b) response to light stimulus, (c) EEG during sleep in an attempt to evaluate changes which might occur in cortical functions as a result of CO₂.

a. Since evaluation of EEG takes considerable time, no comment can be made at the present time.

b. Flicker frequency. The excitability of the visual pathways can be measured fairly well by flicker fusion frequency. Taken on 20 subjects once or twice a week, the flicker fusion frequency did not show any

significant drop throughout the exposure to CO₂. Judged from these measurements no depressive effects of CO₂ on the excitability of visual pathways could be detected.

c. Sleep electroencephalogram. The first step in the evaluation of an EEG during sleep was made in counting the number of movements occurring in comparable periods: during the first hour, which was recorded continuously; during the first 10 minutes of the second hour; during the first 10 minutes of the third, fourth, and fifth hours. As has been shown by Brazier et al ⁽¹⁾, every movement during sleep is connected with a state near awakening, as judged by the increased number of alpha waves in the EEG. The number of movements could be used, therefore, as an indication of the depth of sleep. An increased number of movements would indicate a decreased depth of sleep. Fifteen subjects were investigated prior to exposure to CO₂, during the first two weeks of exposure to CO₂, during the fifth and sixth weeks of exposure to CO₂, eight days post exposure, and four weeks post exposure to CO₂. The number of movements during the first hour and during the following periods was increased under CO₂ exposure compared with the pre- and post-control periods. This means that during exposure to CO₂ the depth of sleep is reduced.

6. Serum: Measurements of the electrolyte and water composition of the plasma and urine were made to determine what degree of respiratory acidosis might occur under exposure to this concentration of CO₂ for a long period. The average changes which occurred in the electrolyte composition of the serum were small and in keeping with the appearance of a very mild respiratory acidosis, which was well compensated at all times.

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(1) Brazier, Mary A.B., and Beecher, Henry K. "Alpha Content of the Electroencephalogram in Relation to Movements Made in Sleep, and Effect of a Sedative on This Type of Motility." J. Applied Physiol. Vol. 4, No. 11, pp 819-825 (May 1952).

a. The average serum pH was 7.34 in the control period. This fell to 7.30 and remained at about this level for the first 20 days under CO₂. It then rose to the control level, where it remained for the rest of the experimental period. There was a slight and probably not significant fall at the end of the period on air which followed the CO₂ exposure.

b. Serum bicarbonate showed a slight increase above control values during the CO₂ period which was in keeping with the small rise in alveolar CO₂ tension. The values returned to the normal range in about one week on weather air.

c. The control levels of serum sodium showed considerable variation, but it appears that there may have been a very slight increase in the middle period of CO₂ exposure.

d. Serum chlorides showed a slight rise at the same time as the serum sodium. These changes may well be due to analytical error or to some change in the water content of the serum not presently apparent.

e. Serum calcium was approximately constant throughout the experiment.

f. Serum phosphate showed a rise during the entire CO₂ period, with a peak at the end of the tenth day. These values returned to control levels within a week after CO₂.

g. Serum water showed no apparent change.

7. Urine Changes in the electrolyte composition of the urine are probably only significant in terms of total balance. To date the intake data have not been collated, so it is impossible to draw any conclusions at this time. However, the urine bicarbonate shows some changes which probably are significant.

a. Urine bicarbonate remained within the control range until the 13th day of CO₂ exposure. At this time it began to rise, reaching a peak the 26th day. By this time it was some seven times the control value (0.5 millimoles per day). During the last week of the experiment in a five-day

period the urine bicarbonate fell to control levels, only to return again for two days before the finish of the experiment to 15 mM per day. The reasons for this drop, which parallels a similar fall in CO₂ excretion through the lungs, are unknown. Following exposure there was a sharp increase in the bicarbonate excretion, which reached levels of 35 mM. This occurred on the second day after return to weather air. The excretion then returned to normal ranges over the ensuing four days.

b. Urine pH mirrored the bicarbonate curve, as was to be expected.

c. Urine calcium, chloride and phosphate excretions roughly parallel each other but show no apparent consistent trend. The daily average of potassium excretion fell to about one half the control value during exposure to CO₂ and later returned somewhat towards normal. Sodium excretions have not been completely evaluated but would appear to show no spectacular change.

8. Nitrogen balance. Since the intake values are not yet complete, no statement can be made as to changes in nitrogen balance. However, there appears to be no significant variation in the nitrogen content of either the urine or feces, so that unless the intakes change considerably there will probably be little or no gain or loss in total body nitrogen.

Acknowledgment: _____

The assistance of the following who performed the various physiological tests is gratefully acknowledged: Karl-Ernst Schaefer, ML., Head Physiology Branch, MRL, LT Geo. Nichols, Jr. (MC) USNR, Project Officer, Physiology Branch, MRL, LT B.K. Hastings, MC, USNR, LT V.F. Borum, C.T.G. King, PhD., C.R. Carey, P.R. Killion, E.R. Williams, M.C. Flanders, HMC J.P. Mego, HMC W.W. James, HM1 A.J. Kuhlmeier, HM2 H.J. Wilson, HM2 H.F. Measimer, HM2 M.C. Reis, HM2 S.A. Bedard, HM3 R.W. King, HM3 R.C. Brigham, HM2 W.F. Karbum, HM3 J.O. Coleman, HM3 W.J. Petit, HN R.J. Petrusek, HN K.M. Roper, HM3 W. Pupanek.

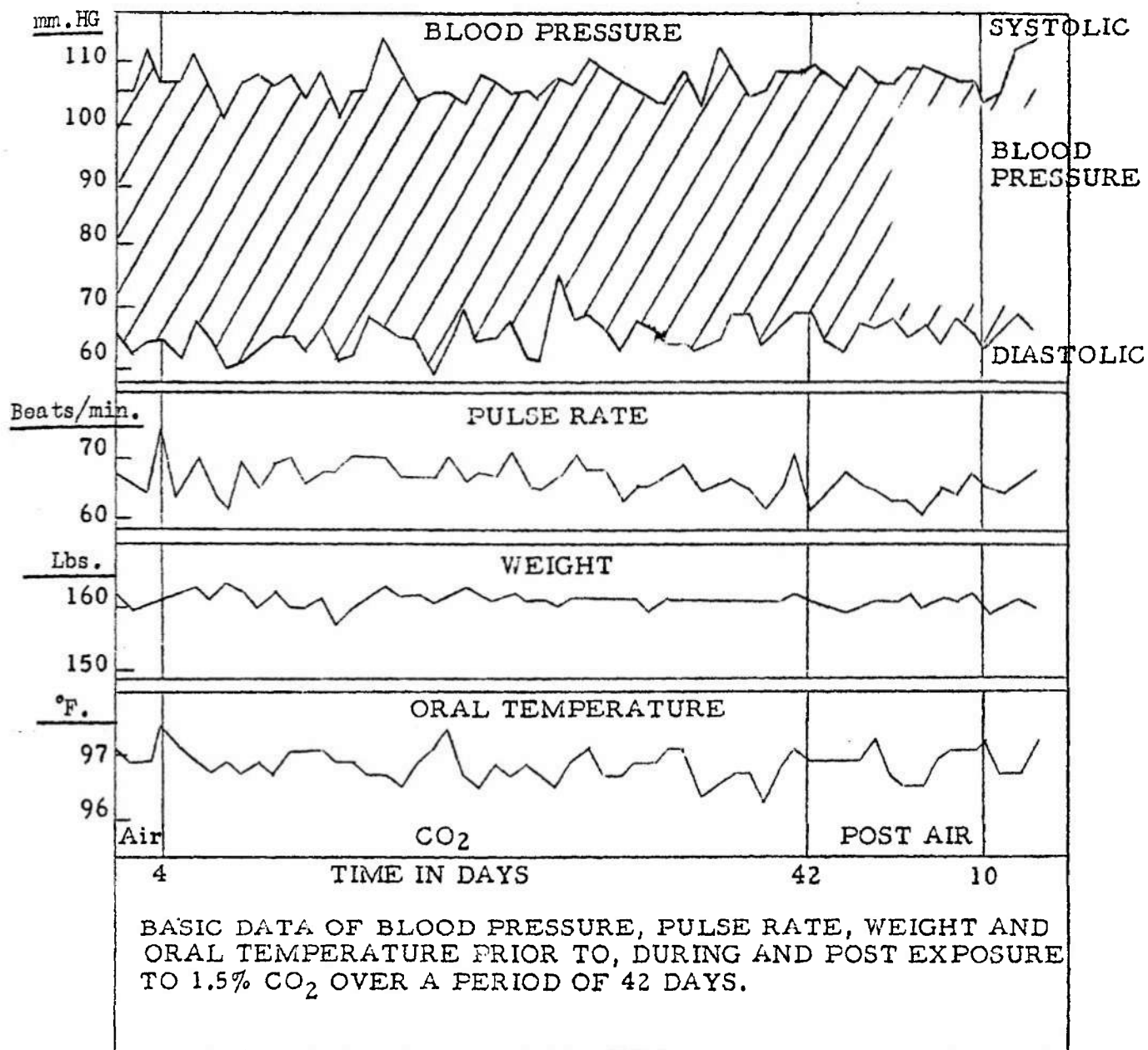
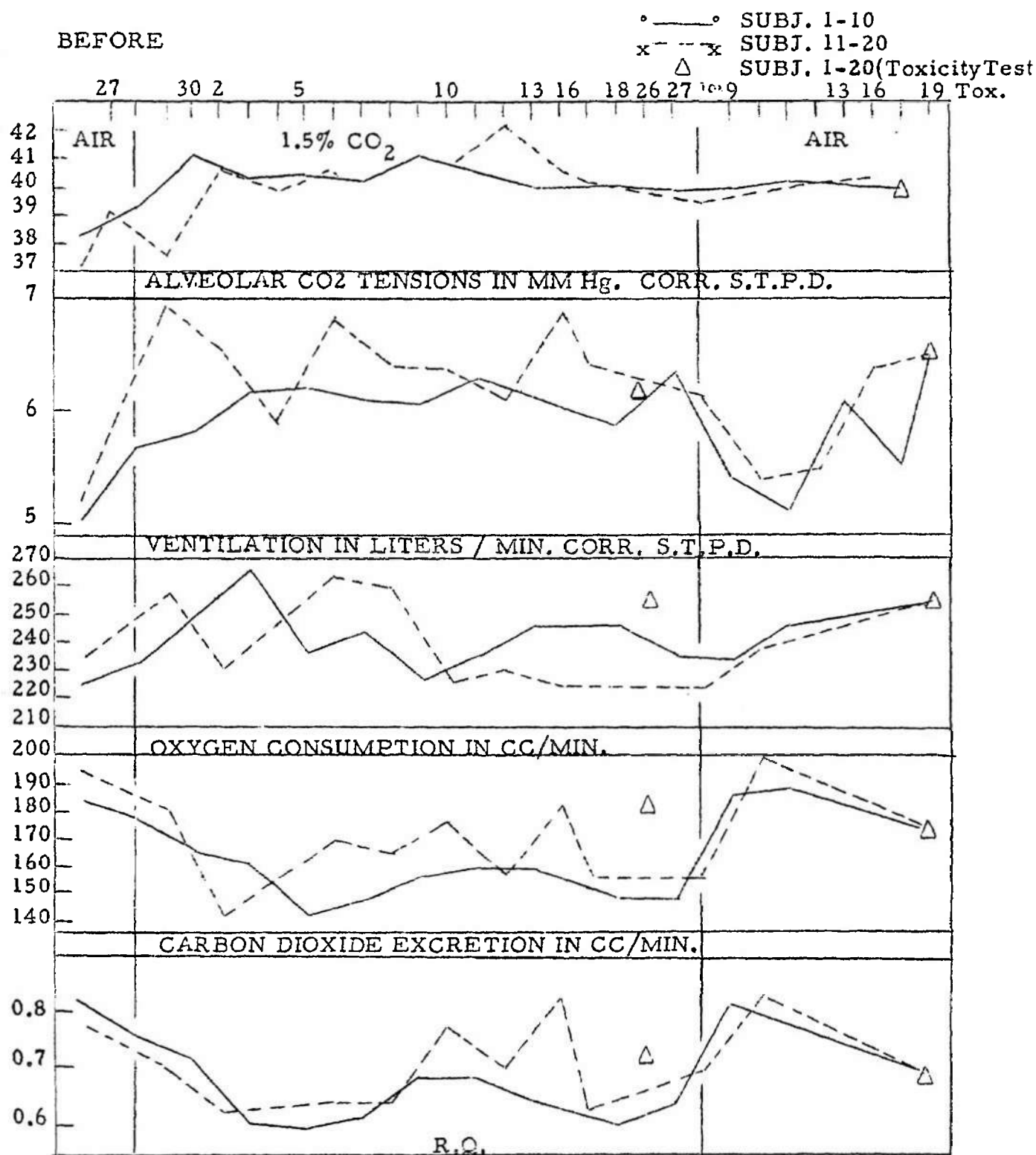


Figure 1



RESPIRATORY MIN. VOL., ALVEOLAR CO₂ TENSION, O₂ CONSUMPTION, CO₂ EXCRETION AND RESPIRATORY EXCHANGE RATIO DURING EXPOSURE TO 1.5% CO₂ OVER A PERIOD OF 42 DAYS. (20 SUBJECTS)

Figure 2

B. Psychiatric Aspects*

The Psychiatric studies of Operation Hideout were necessarily limited by the primary mission of the experiment. The methodology consisted of (1) a pre-experiment interview which was summarized into a brief personality sketch, (2) daily written comments by each volunteer with no attempt to structure or channel the material, (3) casual observation and conversation with various volunteers on daily visits to the submarine, (4) a structured questionnaire of four questions at the termination of the incarceration period.

The psychiatric assessment (there was no attempt at selection) of the volunteers revealed personalities of considerable variety, ranging from compulsive and anxiety patterns to calm, easy going phlegmatic types, from inadequate and immature youths to realistic, ambitious mature individuals, from low average to superior intellectual levels and from apparently well adjusted persons to individuals who displayed obvious signs of deep emotional conflict. It was interesting to see this group of strangers with relatively few characteristics and interests in common mold themselves into a well integrated, loyal group.

Motivation for volunteering was an important clue to certain personality needs. Those with feelings of inadequacy, insecurity or unsatisfied achievement offered their service in order to identify with "something big" or "important". On the other hand, the more materialistic and practical men volunteered to avoid more disagreeable duty such as mess cooking or sweeping streets; while others with realistic consideration of the potential problems felt the undertaking was worth it for the knowledge they personally would gain in addition to the great value to the Navy and their country.

Graphic analysis of productivity as measured by the number of words used on the daily comment cards shows that after the initial output, the mean was 24 which dropped off to 15 and then rapidly rose when the

*The psychiatric examinations and assessments were completed by CDR

submarine was sealed and the CO₂ level increased. The increased productivity persisted for three and a half weeks during which time three peaks were noted. After this the number of words produced dropped rather abruptly and reached a level which was maintained, with only slight variations, until the termination of the experiment.

Productivity correlated roughly with the number of subjective physical symptoms as well as the number of non-physical complaints listed in the daily comment cards. The relatively high output of words lasted about three weeks. This may indicate that the volunteers assumed that only complaints were wanted in spite of instructions to the contrary or that the need to express themselves was important only when the situation seemed adverse. The period during which the subjective physical complaints were increased was considerably shorter than the period of non-physical complaints and the increased productivity which lasted only 10 days. The chief difficulties were head colds and headaches during the period immediately following the increase of CO₂ percentage. The duration of the non-physical complaints or "gripes" persisted double the time of physical symptoms and corresponded with the duration of greater word output.

The meaning of this is not clear but one possible explanation of the variation in productivity and number of physical and non-physical complaints is that (1) anxiety increased upon entering the submarine for the experiment which rapidly disappeared only to reappear at the time the HADDOCK was sealed and CO₂ level increased, (2) the more prolonged period of increased productivity coincided with a period of adaptation to the increased CO₂, effects of incarceration, and the feelings resulting from group interaction, (3) the relatively shorter period of increased physical complaints lasting only until the group became more or less immune to each other's upper respiratory infections, (4) the decrease in productivity noted about three weeks after the submarine was

sealed was probably related to the attitude that "it's half over", and "we can coast in from here". The few spikes in the last half of the run were directly the results of known situational factors such as a talk by the Officer in Charge which disillusioned several of the volunteers and produced considerable temporary hostility.

From the psychiatric point of view it can be concluded that

- (1) No major psychiatric problems were encountered.
- (2) Moderate increases in anxiety occurred at times. There were usually directly associated with and proportional to the situational factors involved.
- (3) Individual performance during the operation roughly correlated with the pre-experiment psychiatric assessment.
- (4) Further analysis of the psychiatric data is indicated.

Mean (N=21)

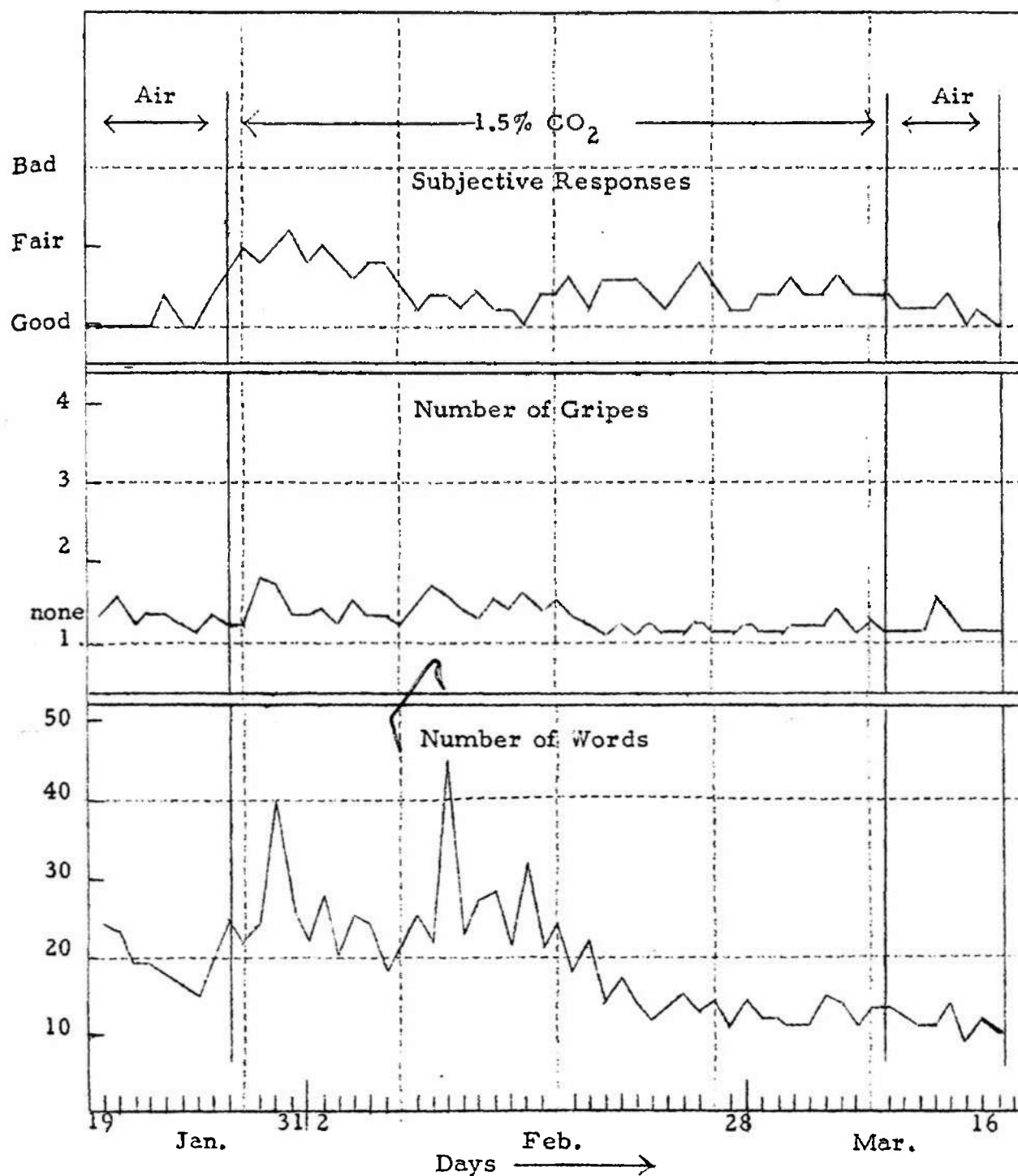


Figure 3.- Responses from Daily Comments

C. Psychological Aspects

The purpose of the measurement of psychological variables during Operation Hideout was to determine the effects, if any, of the CO₂ conditions on an individual's sensory acuity, psychomotor efficiency, attention and memory, problem solving ability, general emotionality, and effectiveness of group interaction.

The persons responsible for the design of the psychological section and for collection and analysis of the data are as follows:

F.L.Dimmick, principal investigator; A. Morris; B.B.Weybrew; D. L. Briggs, Lt. (JG) MSC; P.C.Squires; S.W.Smith; M. Katz; S. Stuntz; M. Bethea, HMI, F. Filarowski, HMC.

1. Sensory and Perceptual Processes

a. Night Vision: The purpose of this experiment was to find out if the ability to see at night would be affected by the conditions to which the men were subjected during exposure to CO₂. A Bio-Photometer was used to obtain ~~threshold~~ threshold measurements during adaptation to darkness. Five subjects were tested once every week. The subject dark adapted to a predetermined brightness level (5.527 log uul), then light adapted for five minutes to 32 footlamberts of white light. The subject then made five successive judgments of the minimal perceptible stimulus brightness. After a total of 4 3/4 minutes in darkness the subject made 10 more judgments.

The median of the five immediate threshold measurements was determined and designated the immediate threshold of that subject for the week. The median was computed for the 10 judgments taken from 4 3/4 to 5 1/4 minutes and this was designated the five minute threshold. The group and individual results for both the immediate and the five minute threshold show no significant changes throughout the experiment. Night vision sensitivity is probably not changed by the conditions of the study.

b. Ortho-Rater Test

Purpose: To measure visual acuity, depth perception and phorias.

Apparatus: Bausch and Lomb Ortho-Rater

Subjects: 10

Procedure: Routine administration each week of Bausch and Lomb tests.

1. Far

- (a) vertical phoria
- (b) lateral phoria
- (c) binocular acuity
- (d) right acuity
- (e) left acuity
- (f) stereopsis

2. Near

- (a) binocular acuity
- (b) right acuity
- (c) left acuity
- (d) vertical phoria
- (e) lateral phoria

Results and Acuity (far and near) persisted unaffected through-
Discussion: out the experiment.

Vertical phorias (near and far) were undisturbed.
Lateral phorias (near and far) tended progressively to the esophoric end of the scale in individual cases, while no group trend was evident.

Depth perception results tended to show improvement, with a drop in the fifth week in the experiment. However, repetition of this test commonly produces improvement which may be considered due to learning (see Figure).

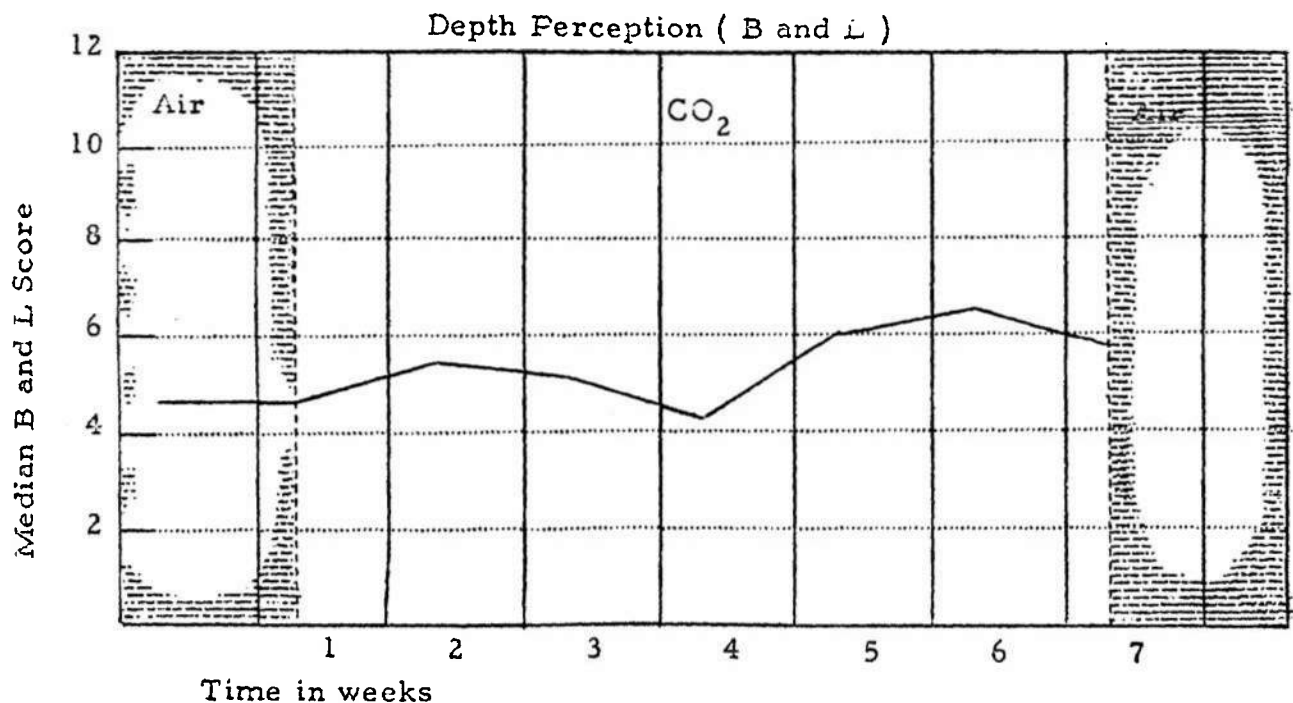


Figure 4.- Results of Ortho-Rater Test

c. Amplitude of Accommodation.

Purpose: To measure amplitude of visual accommodation.

Apparatus: Phorometer, trial lens case.

Subjects: 10

Procedure: Subject fixates reading card at 16 inches. Experimenter places a succession of increasingly negative spherical corrections before S's eye until blurring is reported. Score = $n\Delta-.25$ at blur point. Test was repeated weekly with each subject.

Results: Median blur point score of the group in diopters is plotted weekly through the experiment. The results show a progressively increasing capacity for accommodation. The change is probably due to learning.

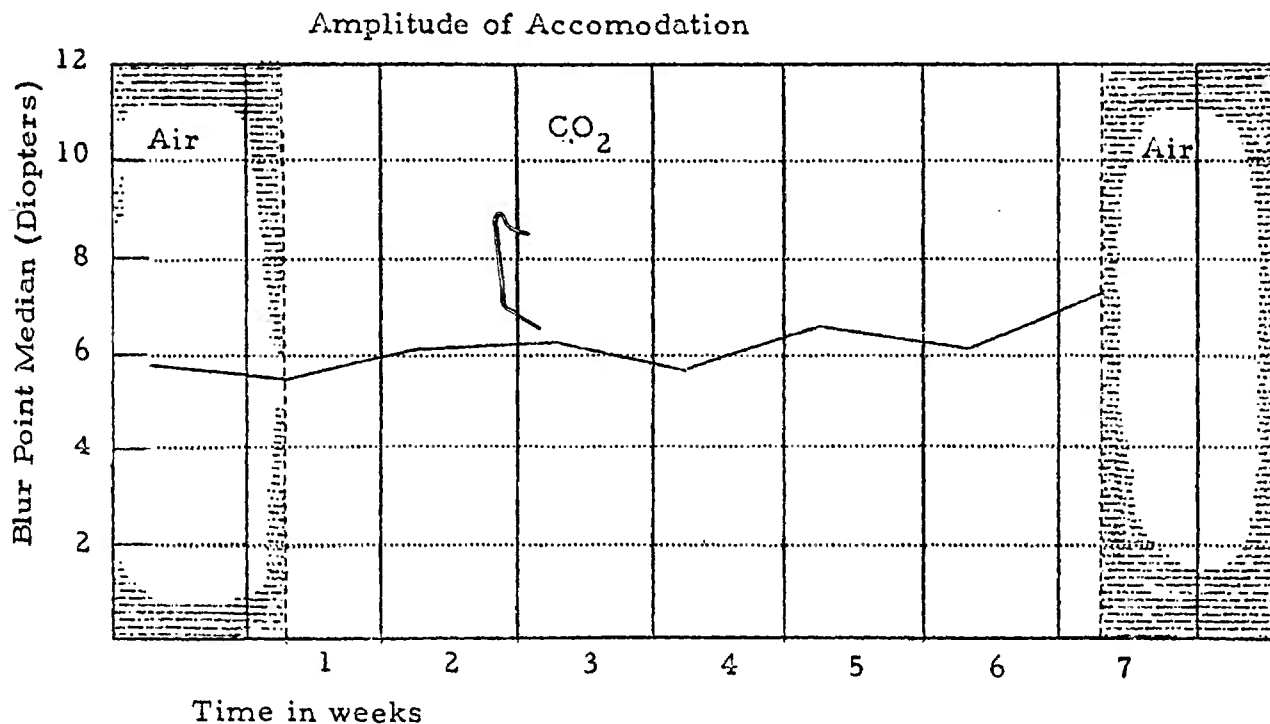


Figure 5.- Amplitude of Accommodation

d. Visual Stereo-acuity

Purpose: To determine the effects, if any, of CO₂ on visual stereo-acuity.

Apparatus: Stereoscopic Trainer M-2 (Bausch and Lomb Optical Company). This is essentially a binocular low-powered microscope. Target used: No. 1

Subject: Number of: 10

Interpupillary distance in millimeters:

(1) Range: 59.5 - 68.0

(2) Average: 64.8

(3) Avg. Dev.: 2.0

Procedure: Subjects required to move target so that it appeared to be directly over the middle vertical line of the reticle, which corresponds to Range dial reading of 5.00 (perfect setting).

At beginning of each sitting subject was shown position of target to which he must approximate as closely as possible. Great care was taken to adjust the subject to the instrument. Precautions were taken to prevent subject acquiring any knowledge of the dial readings. He was not permitted to view field between the settings.

Twelve settings were used--six behind and six in front of position 5.00. Range of settings: 3.50 to 6.50 (one unit equals 12 seconds of arc of apparent field).

Nine test sessions were conducted in the submarine, one per week; two "follow-up" test sessions were thereafter held at MRL.

Results: The data are presented in graphic form..

Distributions of range settings made by the group from week to week tend toward normal distribution form to and including test session of Mch. 4/53.

Best group performance was the very first on board. Poorest performance occurred exactly midway, at the fifth session. From the first to and including fifth session there was progressive deterioration in group performance. Thereafter, improvement over the following two sessions occurred, attaining the level of performance achieved just two weeks preceding the poorest performance (on Feb. 18th).

The average deviations of the group manifest a strong tendency to follow trend of principal data; but note "cross-overs" during periods between Jan. 28th and Feb. 11th.

Summary and Conclusions: The visual stereo-acuity test administered to a group of ten subjects in a submarine under normal air conditions and under CO₂ fails to reveal any deterioration in group performance over a course of nine

test sessions which can with any degree of assurance be attributed to the effect of CO₂. The many uncontrolled variables involved, including emotional and social factors, pose limitations to attributing any specific effect upon visual acuity to CO₂, particularly in view of the fact that the distribution graph shows as much improvement two weeks after poorest performance as deterioration for the two weeks preceding poorest performance.

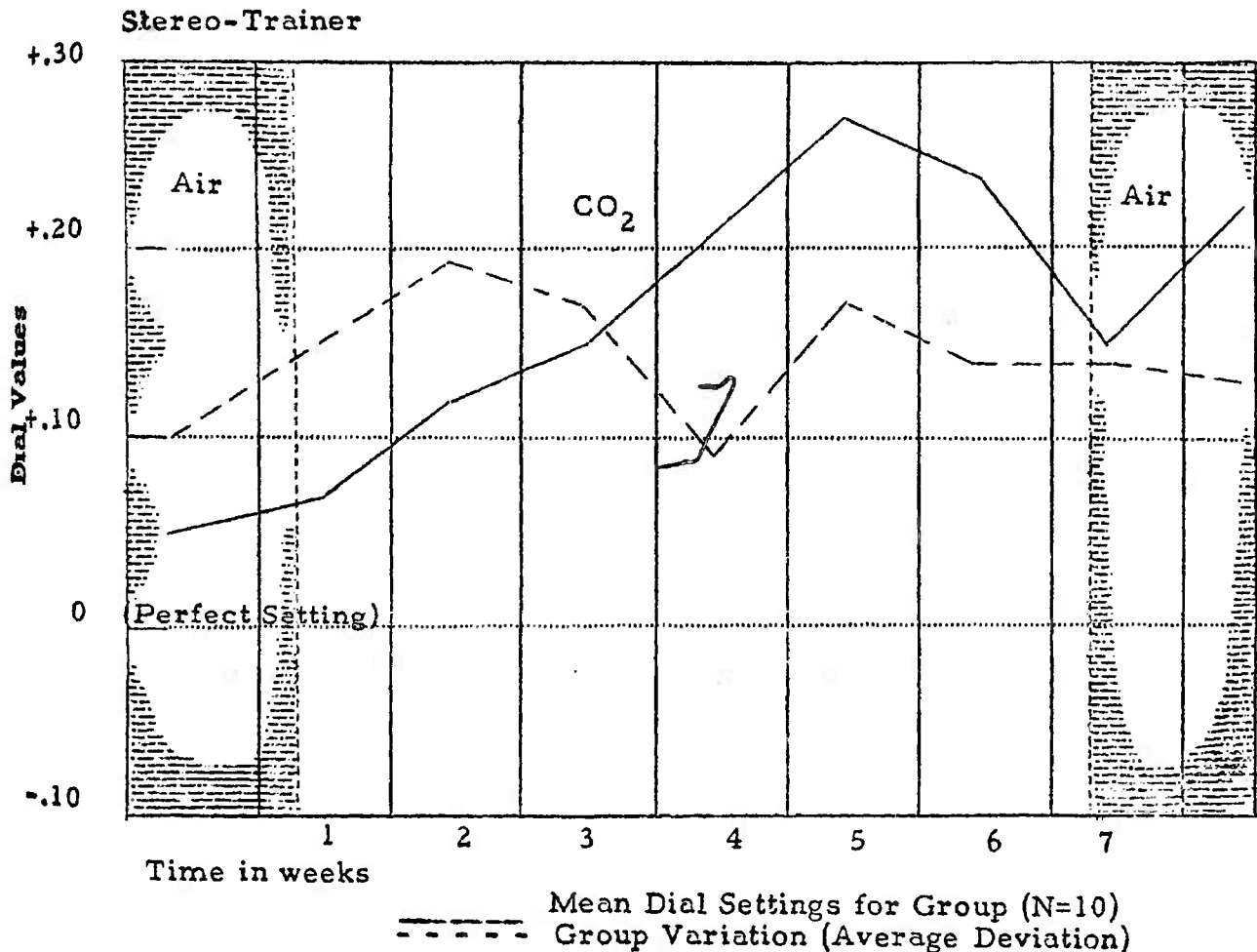


Figure 6.- Stereo-Trainer

e. Pitch Discrimination

Purpose: Since the ability to discern small differences in the frequency of pure-tone sounds is important in the operation of underwater sound-detection equipment, this this was designed to study the effect of prolonged exposure to CO_2 upon the individual's auditory capacity to discriminate these differences.

Apparatus: The Navy Sonar Pitch Memory Test, a series of phonograph recordings identified as USN SDC Device 30-A3, provided the tonal stimuli. These were reproduced by means of a portable Presto playback-amplifier set, through monaural headsets consisting of Permoflux PDR-8 phones mounted in spong-rubber supraural cushions.

Procedure: Each of nine subjects was tested on two days of each week (Tuesday and Friday) during weeks I and II and once a week thereafter. The sound was presented via the headphones to one ear only; at the outset of the series, subjects were instructed to choose the ear preferred. On subsequent tests each subject used the same ear, and recorded his responses on a standard answer sheet. From correct responses by each subject on each test an individual difference-limen (DL) was determined. DL's for each test were then averaged. The results of this procedure are plotted on the following graph.

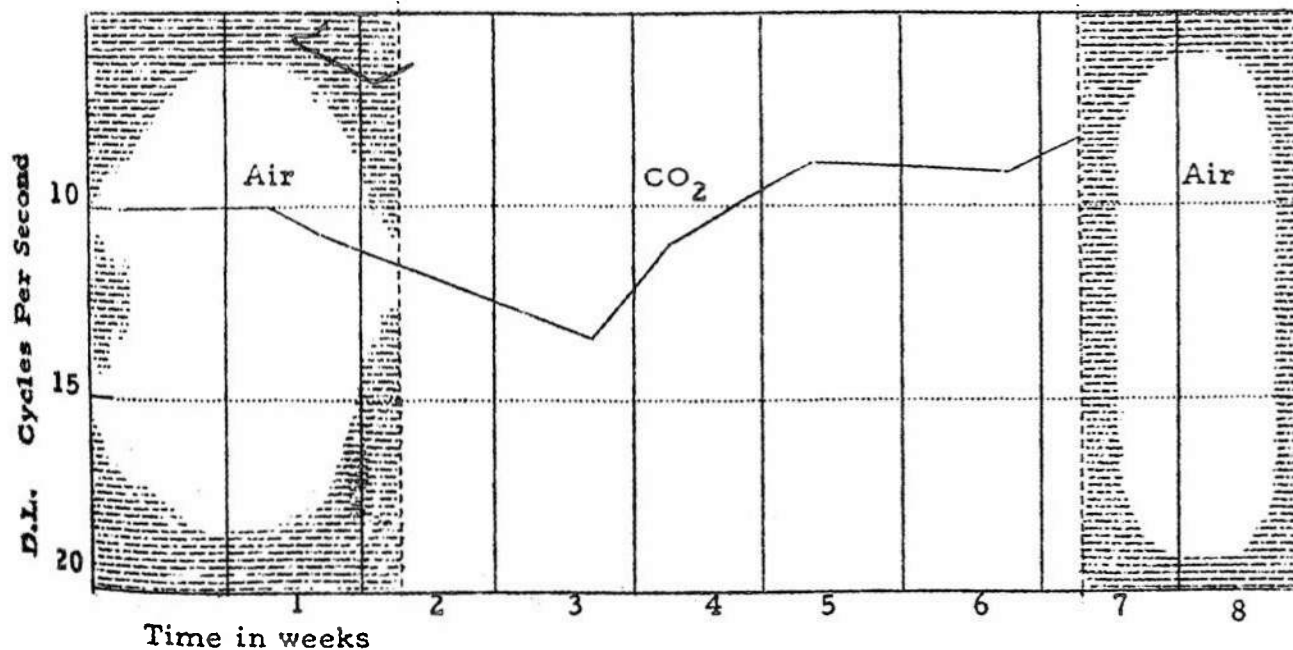


Figure 7.- Pitch Discrimination

Discussion: While the results shown above suggest that some change in average pitch-discrimination occurred during the series of tests, these changes do not approach formal significance. It is possible that analysis of each individual subject's performance might show some significant variation in discrimination as a function of time spent in a CO₂-containing atmosphere.

f. Auditory Acuity

Purpose: The ability to detect sounds of many kinds is basic to the success of voice communication as well as other forms of auditory signalling. These tests were undertaken to determine whether prolonged exposure to CO₂ has a deleterious effect upon the sensitivity of the human ear.

Apparatus: The source of pure-tone sounds used in this test was a standard MAICO clinical audiometer, adapted to a group of ten monaural Permoflux PDR-8 headphones, each pair of headphones was equipped with chamois-covered sponge rubber supraaural cushions.

Procedure: Each of ten subjects was tested by means of a group technique developed in the Naval Medical Research Laboratory, New London. One ear at a time was tested to determine the threshold of audibility of pure tones at 256, 512, 1024, 2048, 4096 and 8192 cycles per second. Decibels hearing loss was computed for each individual ear, and an average loss for the 20 ears of ten subjects at each test frequency was determined. The group was tested twice each week--Tuesday and Friday--throughout the experimental period. Results of these observations are tabulated on the following page.

Discussion: From the data it would appear that the group average hearing loss exceeds the Navy maximum to a considerable degree. However, a high ambient noise level in the testing compartment appears to have intruded a masking effect upon the subjects' auditory thresholds. The effect of this mask is about what would be expected from machine noises: there appears a greater loss for low-pitch tones than for those above 1024 cycles per second.

The week-to-week and within-week variations in acuity suggested by the data may actually reflect variations in compartment noise-level.

SHOWING WEEK-BY-WEEK HEARING LOSS FOR PURE TONES
IN DECIBELS RE: NORMAL THRESHOLD (AV. OF 20 EARS)

		Frequency in Cycles Per Second					
Week		256	512	1024	2048	4096	8192
1	Tues.	24.5	28.2	22.5	18.5	20.0	17.1
	Fri.	33.2	31.7	33.0	22.2	16.2	9.5
	(No data taken during Week 2)						
3	Tues.	33.2	26.5	21.7	16.7	20.0	8.7
	Fri.	32.7	29.7	26.7	16.6	21.5	11.2
4	Tues.	28.7	24.7	21.5	15.7	16.7	11.7
	Fri.	25.5	22.7	22.7	15.0	17.0	13.5
5	Tues.	27.0	23.4	22.5	15.0	19.5	10.7
	Fri.	33.0	26.2	22.7	19.2	19.5	10.5
6	Tues.	25.7	27.0	23.7	16.7	19.7	11.2
	* Fri.	28.4	27.5	29.7	21.2	16.2	5.0
7	Tues	31.5	27.5	28.5	20.0	20.7	11.0
	Fri.	31.0	27.5	23.7	18.0	20.7	14.0
8	Tues.	32.5	27.0	23.0	19.7	16.7	10.7
	Fri.	26.0	24.7	21.5	20.0	20.2	14.0

* Average losses for 16 ears.

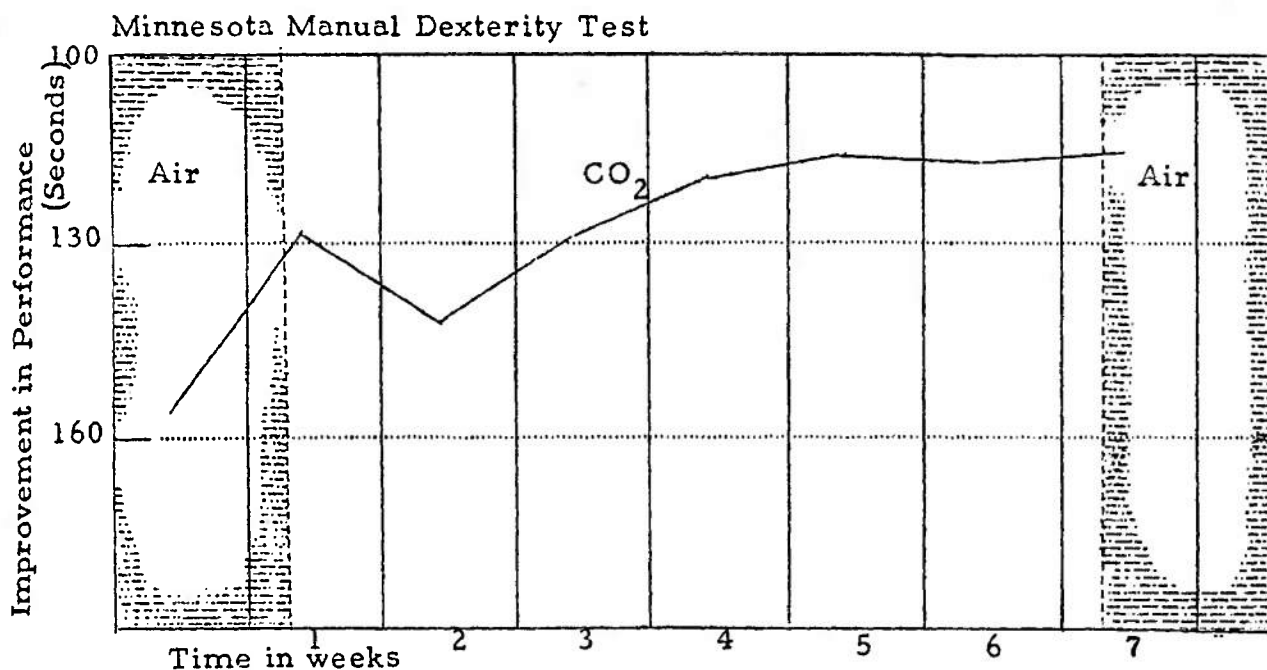


Figure 8.- Minnesota Manual Dexterity Test

b. Letter Cancellation

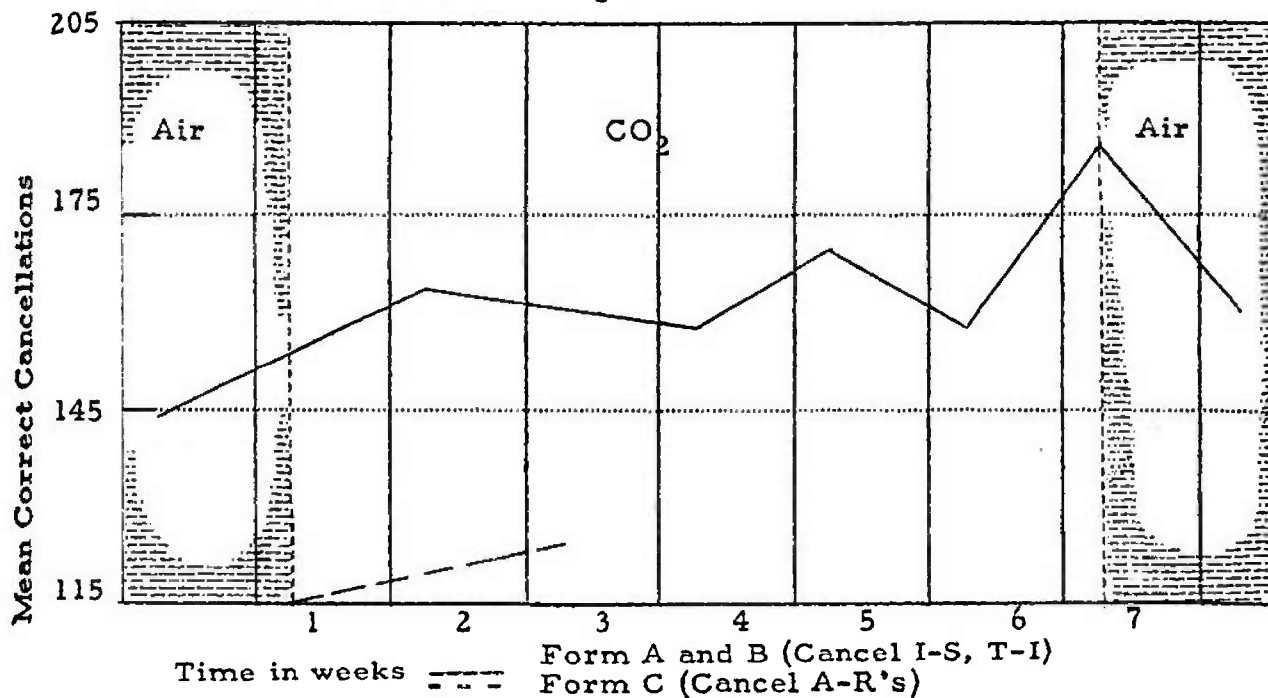
Purpose: Assuming this test measures speed of simple rapid movements ("aiming" as well as some perceptual factors), the purpose of this measurement was to determine any possible effects of the exposure to CO₂ on these particular behavior areas.

The Cancellation Test: Two sheets of typewritten mimeographed textbook material with a known number of experimental letters on each page made up the test. The subjects were instructed to cancel as rapidly as possible a given letter on the first page (time 2 min.), rest a minute then cancel a different letter on the second page (again 2 min. time). Three comparable sets of these tests were compiled, to be used in non-consecutive experimental periods. The pages of the test were also reversed to minimize serial effects.

Procedure: Ten subjects were tested in a group in the control room of the submarine at weekly intervals throughout the experiment. Each individual's score consisted of the total correct cancellations on both pages of the test. The measures and incorrect cancellations were negligible; hence, they were not corrected in the composite score.

Results: The results for the 10 volunteers are presented graphically in terms of mean letters correctly cancelled in each experimental condition. The variability of the distributions at all experimental periods are reasonably symmetrical (P.E. varies from 10-14 cancellations) with a moderate tendency towards negative shewness. It is to be noted that the data for the second measurement in air (cancelled A's and R's) and the second week in CO₂ are graphed separately due to empirical evidence that this form of the test was not equivalent to the IT, TI, SI, IS forms. This form was consequently eliminated in the subsequent experimental periods.

Letter Cancellation Test - Figure 9



Discussion: Because of unexpectedly high individual differences and in some experimental periods extreme deviations, the significance of the changes due to factors other than test unreliability is reserved until further analysis of the data has been completed.

c. MacQuarrie Test for Mechanical Ability

Purpose: To ascertain the effects of exposure to CO₂ upon performance measured by the MacQuarrie Test.

Discussion of the Test Instrument: The MacQuarrie Test for Mechanical Ability consists of a battery of subtests which are only slightly intercorrelated, hence must be discussed separately, as follows:

The MacQuarrie Sub-tests with the Performance Area* Assumed to be Sampled

Sub-Test	Reported Reliabilities	Factor or Factors Assumed to be Measured by this Sub-Test	Description of the Operation by which Factor was Measured
A. MacQuarrie Tracing	.80	Perceptual ability and some general manual agility factor,	Subject draws a line through small openings in a series of vertical lines.
B. Tapping	.75	General manual agility. Some possibility of a verbal factor.	Requires subjects to make pencil dots as rapidly as possible.
C. Dotting	.74	General Manual agility, aiming,	Requires the subjects to place one dot in each of small circles spaced irregularly.
D. Copying	.86	Spatial.	Copies a series of designs by coordinates.
E. Location	.72	Spatial Factor.	Subjects locate points drawn on a large scale and transpose them into an area drawn on a smaller scale.
F. Block Counting	.80	Spatial.	Requires the subject to visualize space by telling how many blocks in a pile touch a given block.
G. Pursuit	.76	Spatial.	Trace line through a tangle pattern.
Total Score	.90		

* These assumptions are based somewhat on a study by Harrell, T.W., "A Factor Analysis of Mechanical Ability Tests," Psychometrika, 1940, 5, 17-33.

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Ten of the twenty-two subjects were tested in the control room twice in air in the pre-experimental control period and one time in the post-test air period. There were six consecutive weekly measurements in the CO₂ condition.

The results for each of the sub-tests are presented graphically in terms of medians, \bar{Q}_3 and \bar{Q}_1 for each experimental period, in

Discussion: Perceptual factors (and some Manual Agility factors) as measured by the MacQuarrie Tracing Sub-test show a moderate trend toward less efficient performance, the greatest drop occurring between weeks II and IV in CO₂.

Aiming, as measured by the Tapping and Dotting sub-tests, gives slight evidence of a trend toward improvement (learning).

Spatial ability as measured by the Copying sub-test shows one significant change (loss of efficiency) between weeks V and VI. This decrement may be, to an extent, the result of lowered motivation of the group, as indicated by the self-rating on motivation. See Figure

Spatial ability as measured by the Location Test shows a trend toward improvement with a moderate reversion in week III.

Spatial ability as measured by the Block Counting Sub-test shows a gradual but slight trend toward improvement.

Spatial ability as measured by the Pursuit sub-test shows a fairly substantial drop group-wise between weeks I and II in CO₂.

The total MacQuarrie Score appears to represent a gradual trend toward improvement. There appears to be no remarkable change in the over-all performance on the MacQuarrie Test; however, there is some indication that behavior involving visual perceptual ability, and also operations involving spatial ability may be slightly retarded in the first weeks in CO₂. A parallel control group design would, of course, be necessary to test the hypotheses involved.

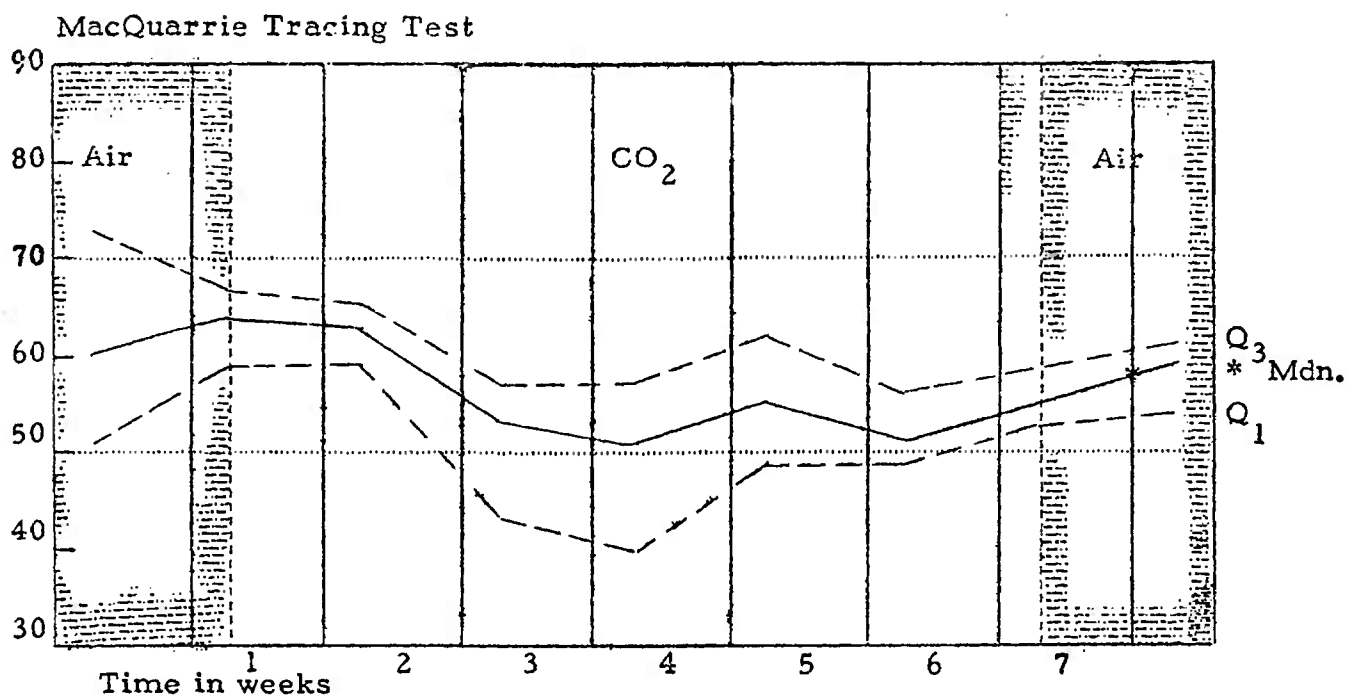


Figure 10. - MacQuarrie Tracing Test

* = N=5

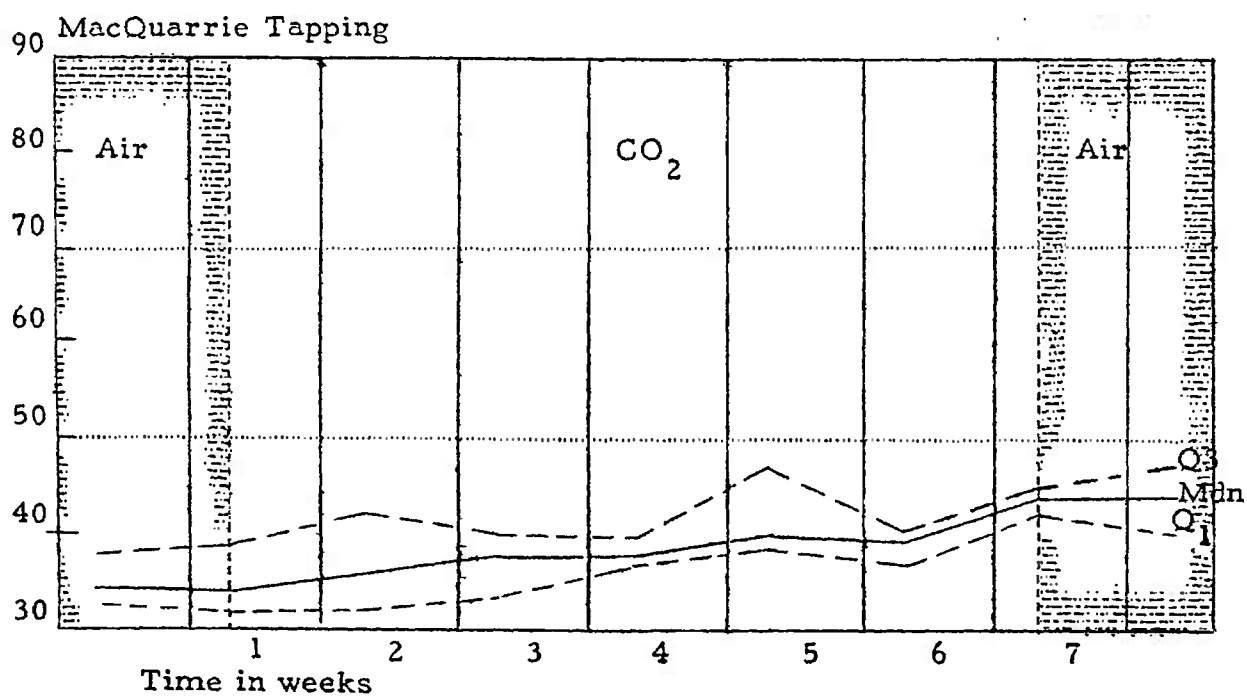


Figure 11. - MacQuarrie Tapping Test

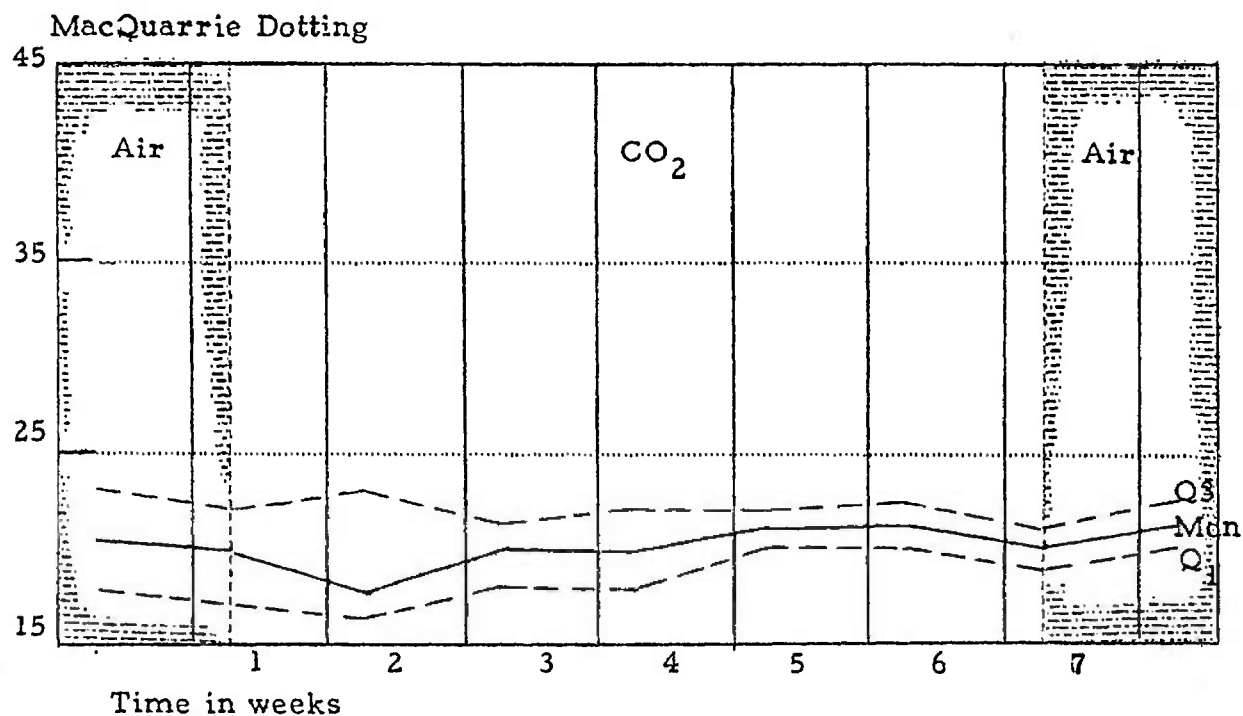


Figure 12.- MacQuarrie Dotting Test

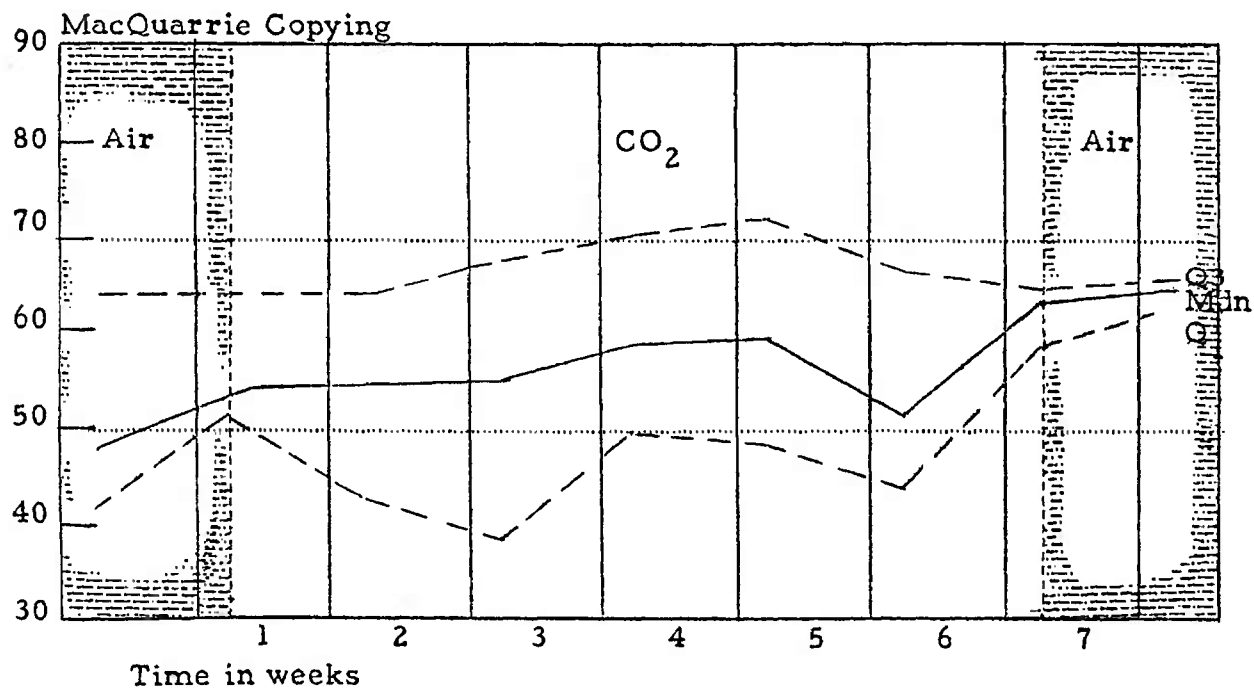


Figure 13. - MacQuarrie Copying Test

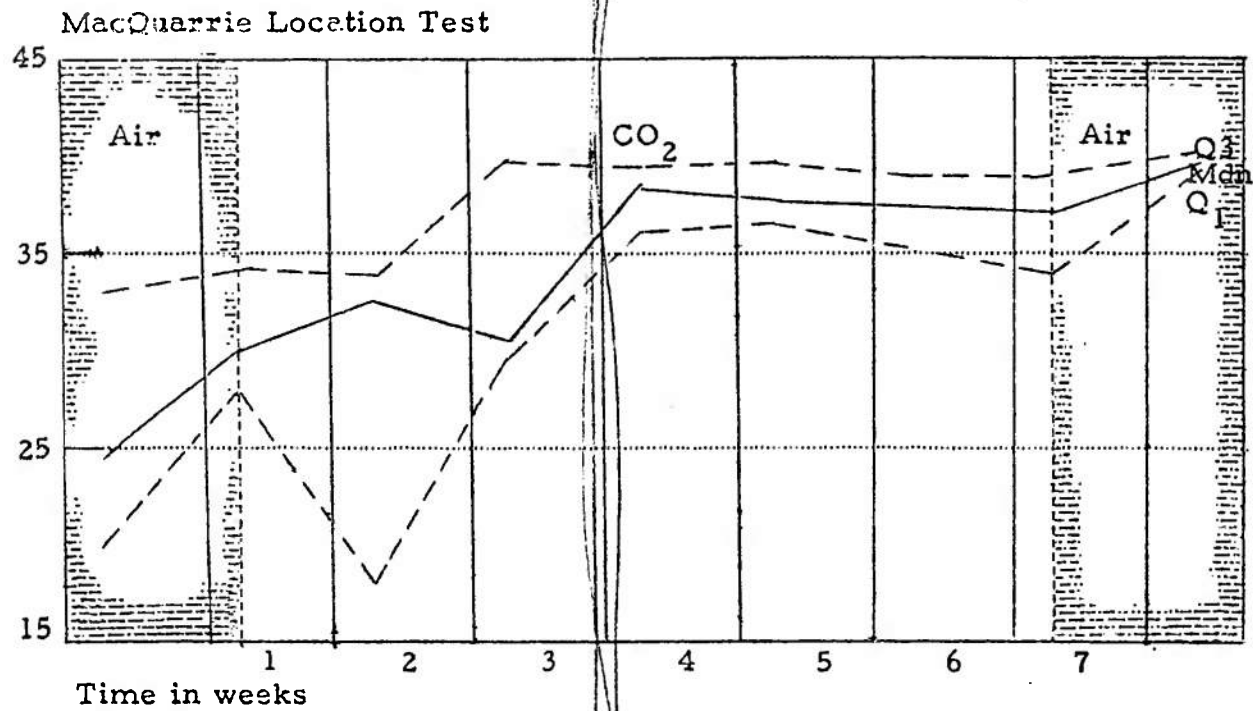


Figure 14. - MacQuarrie Location Test

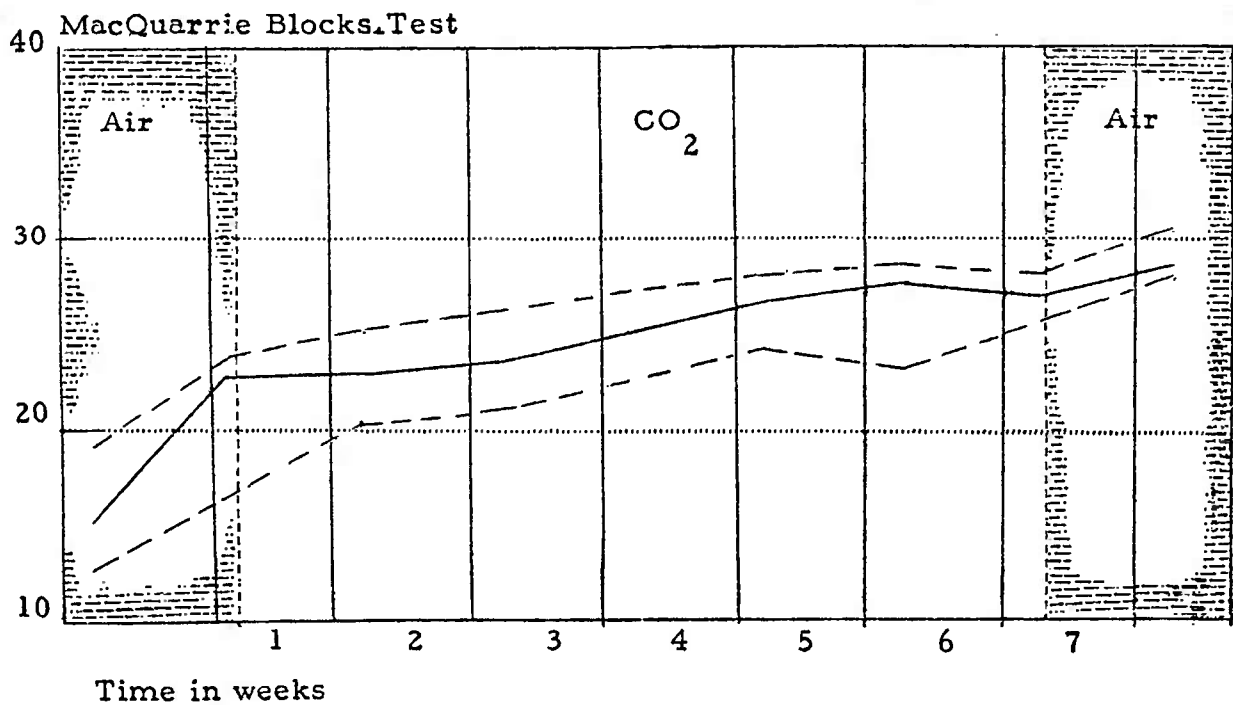


Figure 15.- MacQuarrie Blocks Test

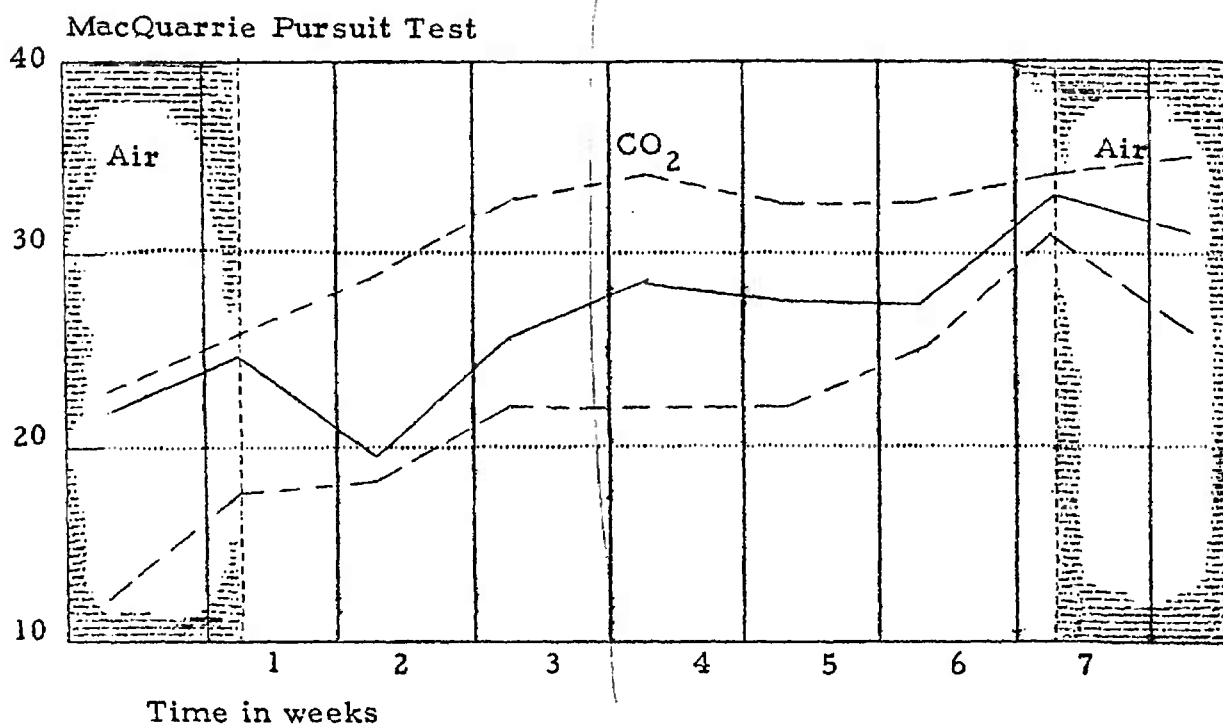


Figure 16. - MacQuarrie Pursuit Test

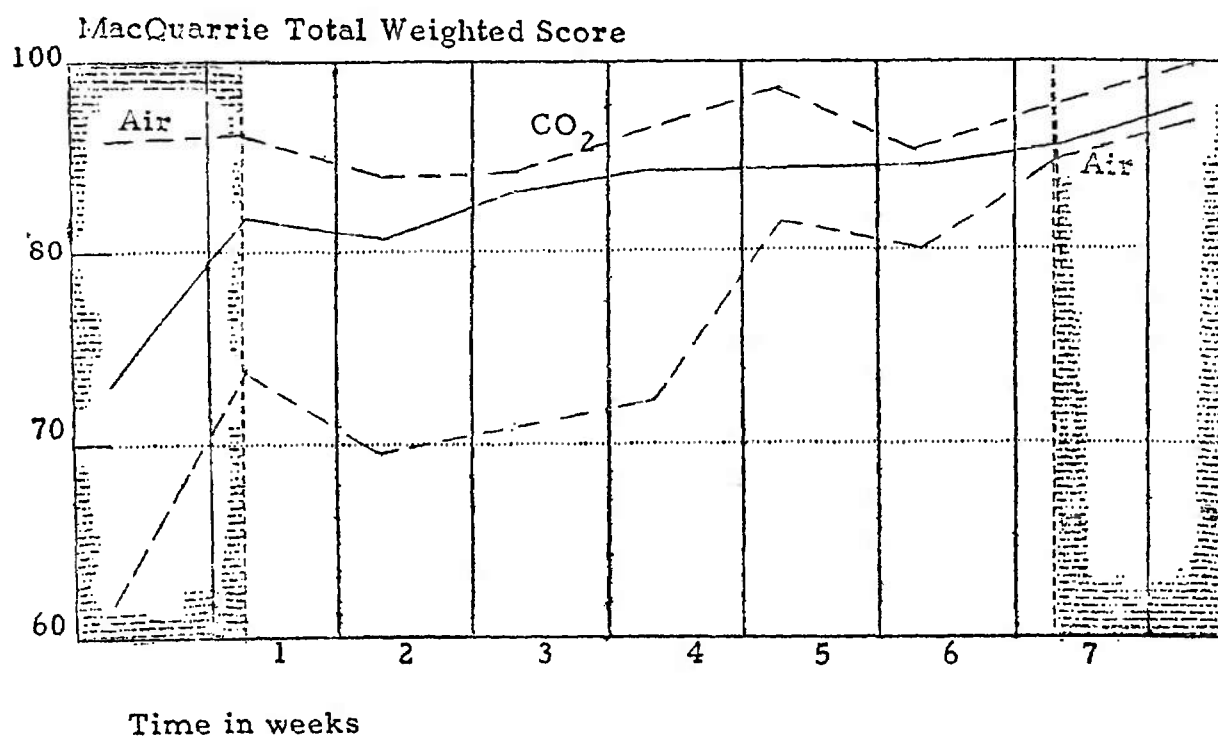


Figure 17. - MacQuarrie Total Weighted Score

d. Steadiness and Aiming Test

Purpose: To measure hand-arm steadiness and aiming

Apparatus: Nine-hole steadiness tester, Cenco impulse counter, stopwatch.

Procedure: (a) Steadiness - Subject holds the stylus in second smallest hole for thirty seconds, with instructions not to touch the stylus on the sides. The score was the number of contacts per 30 second interval.

(b) Aiming - Subject inserts and withdraws the stylus as rapidly and accurately as possible into each of the nine holes diminishing in size.

Results:

Steadiness - The data is presented graphically in mean contacts per 30 seconds for the twenty-two volunteers measured weekly. The first session in the CO₂ conditions indicates a marked reduction in the number of contacts (increase in steadiness) with a subsequent return to the control level in the second experimental measurement. There are no significant changes in the group mean performance in the experimental periods following week 2. The only conclusion warranted from the data is that the group appeared to be significantly steadier, as measured, 24 hours after the outset of the CO₂ conditions than at any other time during the experiment.

Aiming - Mean group ratios of contacts to time per trial are plotted by weeks. The data show an increase in ratio of contacts to time per trial during the first session under CO₂, with stabilization at a level higher than the control ratio. Pending further analysis, the trend may signify a decrease in aiming accuracy as measured by the number of contacts per unit time for the trial. There is, at the end of the experiment, a revision toward the control level.

The changes observed are, however, of little magnitude and may very well be of practical negligibility.

Summary Conclusions

- (1) Twenty-four hours after the CO₂ conditions began the group appeared much steadier as measured by the hand-arm steadiness apparatus.
- (2) Apparently there is no effect of the CO₂ conditions on the perceptual and motor skill demanded by the aiming task.

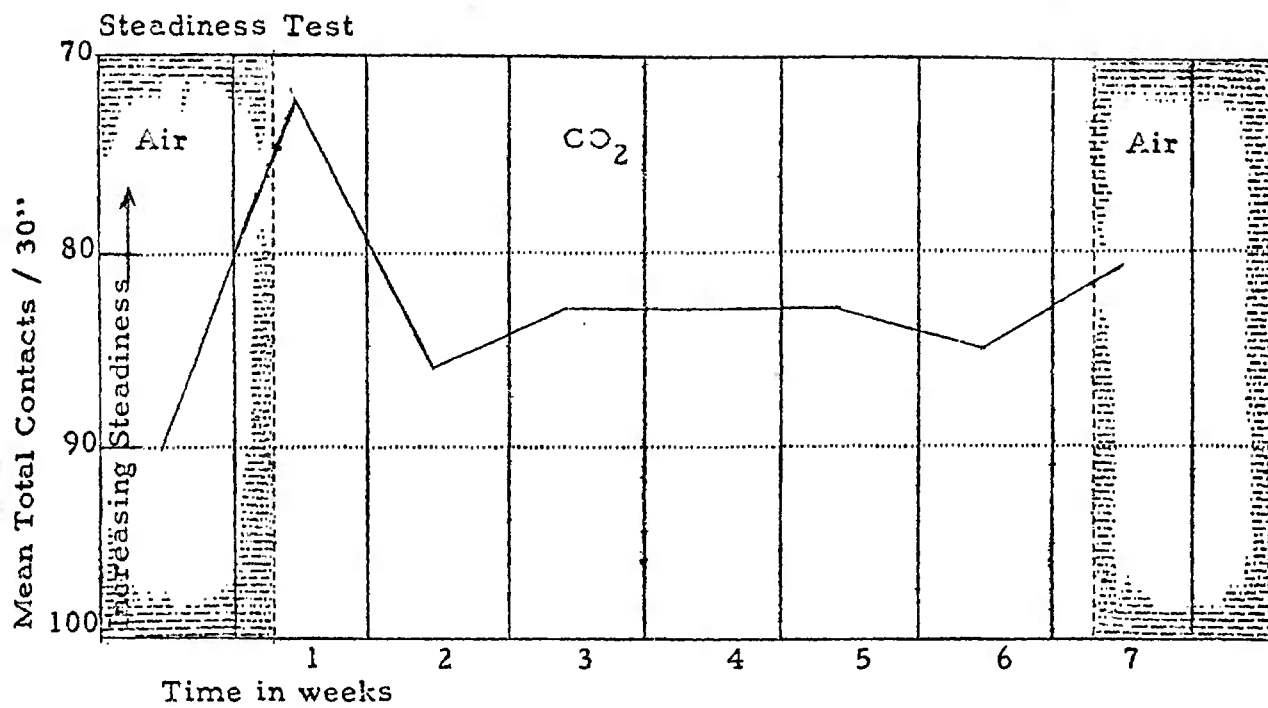


Figure 18. - Steadiness Test

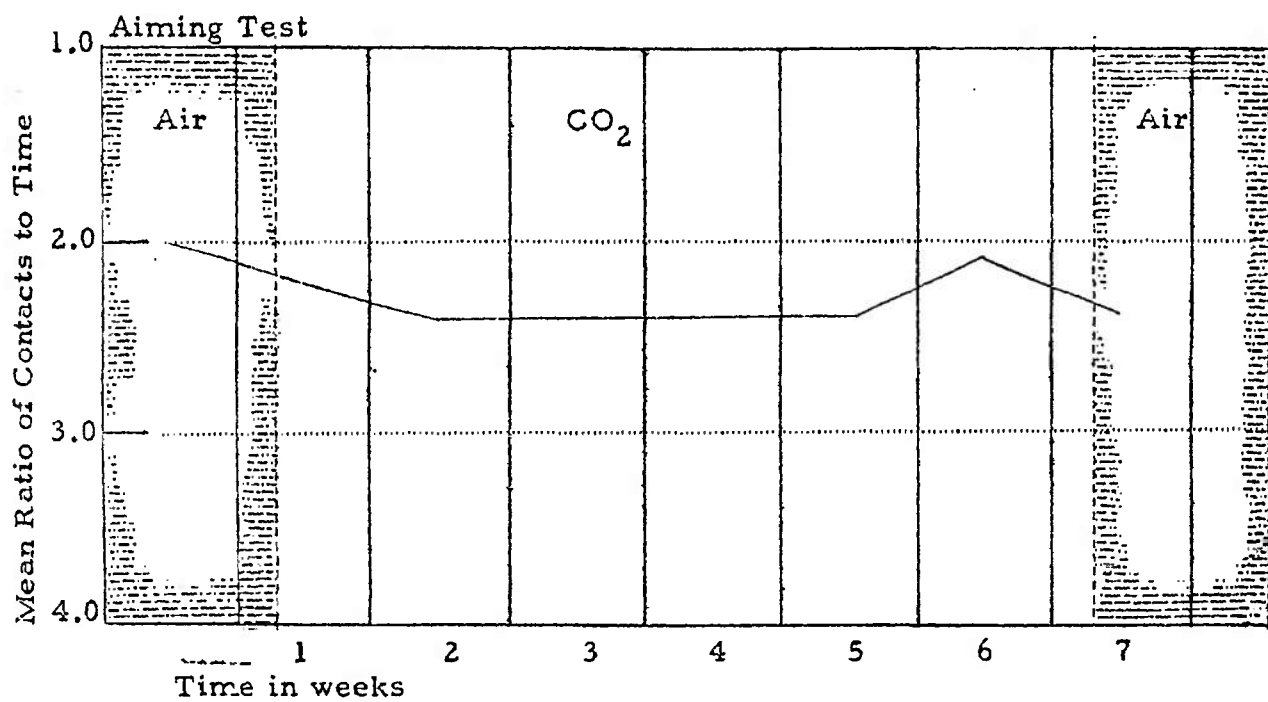


Figure 19. - Aiming Test

e. Body Sway (Ability to stand without swaying)

Purpose: The purpose of this experiment was to find out if the ability to stand with eyes closed without swaying forward or backward would be affected by the conditions to which the men were subjected during Operation Hide-out.

An ataxigraph was constructed which converted the forward-back movement of the subject by a lever system to exclusion of a recording pen on a constantly moving paper. The movement was picked up from a helmet arrangement which was placed on the head of the subject.

Twenty-one subjects were tested each week. The subject stood erect with eyes closed for two 2-minute periods. A brief rest period with eyes open was given between the two test periods.

Results and Conclusions:

A continuous record on the paper was marked off into the four 1-min periods and the length of the recorded line in each 1-minute period was recorded with a map-measure. One body sway measure for a subject for a week was the median line length of the four individual measures. The other measure was the range (highest minus lowest) of the four individual measures.

The group results show a decrease in sway (increase in steadiness) during the first 4 weeks and then a gradual increase in sway the fifth and sixth weeks and a sharp increase the seventh week. Sway decreased sharply again on the eighth week. The same general picture is true for the group for both medians and range measures. Further analysis must be made concerning individual results.

The final post boat measurements and the control group measurements have not been completed as yet. It would therefore be inopportune to make interpretations and conclusions at the time.

f. Hand Dynamometer

Purpose: This measurement was designed to investigate two major hypotheses viz., (1) Effects of the CO₂ situation upon muscular strength as measured by the maximum grip and (2) Effects of CO₂ confinement on some motivational factor (Will-Perseveration, Cattell) assumed to be measured by the maximum time an individual can maintain a constant grip.

Apparatus: Standard hand dynamometers were used to measure strength and duration of grip in all experimental sessions. Because of a delay in receiving shipment on the Stoelting Hand Dynamometer originally proposed for the research, substitute apparatus was employed. In the first six experimental periods the KNY Scheerer Hand Dynamometer (Made in Germany), units in kilograms, was employed on all volunteers. Due to equipment failure in the fourth experimental week, the originally proposed apparatus (Then in stock) was employed in the remaining periods. Since no simple linear transformation of units was possible because of different grip shapes, the pre-test and Experimental week (1-5) should not be compared to the Post-test and experimental week (6-8.)

Procedure: All twenty-two volunteers were tested on the submarine twice before the outset of the CO₂ conditions and then weekly for six weeks, the post-test control period coming six days after air was again admitted into the submarine.

The dynamometer test was administered individually by Katz and Weybrew. On the strength test the volunteers were instructed to "squeeze this instrument as hard as possible". The strength score consisted of the mean of four trials with 1 minute rest between each trial.

The instructions for the preservation test were as follows: "Squeeze the pointer up to this marker and hold it there as long as possible."

The marker setting was arrived at by taking two-thirds of the strength score. The criterion for relaxing the grip was arbitrarily set at 5kg (10 lbs) drop. Time was measured in seconds by means of a standard stop watch for three trials. Two duration scores were recorded, the maximum and the median of the three trials with one minute rest between trials.

The results are presented graphically on the opposite page.

The within group variability for each of the experimental periods was reasonably symmetrical for both the Perseveration and Strength tests. The maximum perseveration score for each of the experimental periods shows a slight tendency towards negative skewness (Q varying from 4-7 kilograms with the KNY Scheerer apparatus and from 5-12 pounds with the Stoelting Hand Dynamometer.

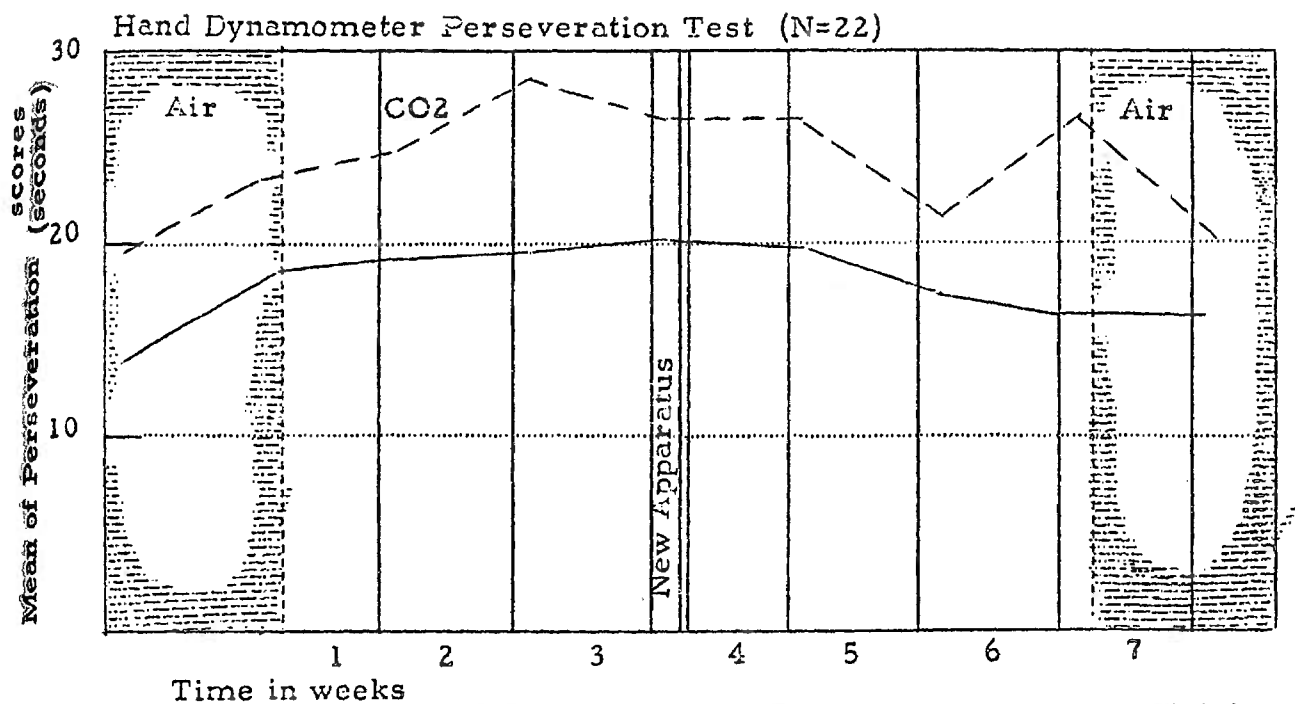


Figure 20.- Hand Dynamometer Perseveration Test (N=22)

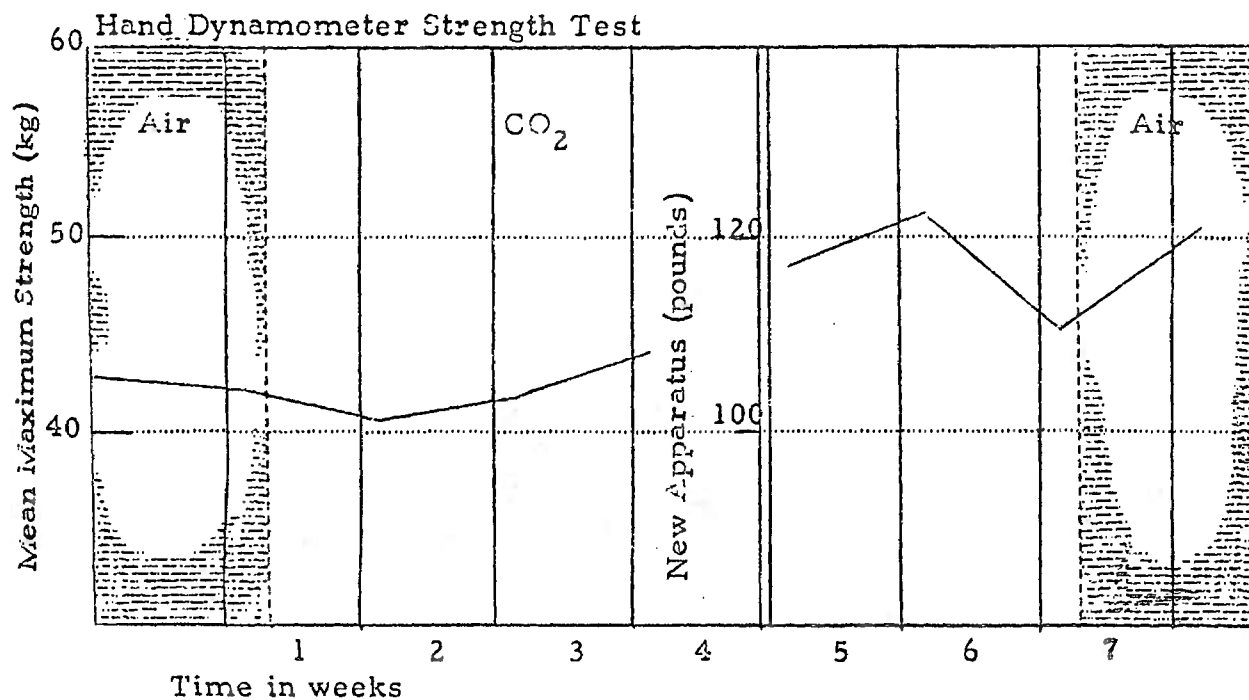


Figure 21.- Hand Dynamometer Strength Test 39 -

Perseveration Test

Recognizing the possible effects of extreme individual deviations from mean group scores, the data are suggestive of an improvement in scores (ability to stick to an unpleasant task?) up to about two weeks in the experimental situation. There follows a progressive loss in the perseveration scores of the group up until the seventh week at which time a high mean perseveration score is again obtained. The post-experimental control data shows a reversion (drop in perseveration score) to the week six level.

No definite trends can be inferred from the data with the possible exception of the gradual increase in perseveration scores up until week six at which time the experimental situation was changed because of apparatus failure. Although empirical attempts were made to equate the two dynamometers, the downward trend after week five cannot be positively related to factors other than different equipment. The enhanced group perseveration scores twenty-four hours before the outset of the post-experimental air period are felt to be a spurious result of a fairly obvious "end-effect" observed in the group as a whole.

Strength Test

Comparing the pre-test control with the subsequent strength scores in the CO₂ environment, no significant changes other than a slight trend in the means towards enhancement (Maximum mean change: 1 1/2 kg, or 3 lbs) can be ascertained. Comparing the data for experimental period 5-7 (different apparatus) with the post-experimental control in air, there appears some slight suggestion of an increase; however, the effects of extraneous variables including possible "end-effects" cannot be determined from this preliminary analysis.

g. Two-Hand Complex Tapping Test

Purpose: To measure complex rapid hand-eye coordination

Apparatus: Two-hand complex tapping board, stop watch, Cenco impulse counter.

Ss: .1

Procedure: The apparatus was set up with a different spatial pattern to be tapped by each hand. (A full description of the apparatus may be found in Birren and Fisher's Standardization of Two Tests of Hand-Eye Coordination. U.S.N.M.R.I., Res. Proj. X-293 Report #C, 1945.)

In each experimental session the subject tapped corresponding numbers simultaneously as rapidly as possible with both hands for five one-minute trails. Correct simultaneous taps were recorded by impulse counter.

Most of the subjects received eight trial practice sessions before entering the boat. During the experiment each subject performed once each week.

Results: Scores are presented as mean number of taps per minute for each session.

Conclusions: The data indicate that performance continues unaffected under this concentration of CO_2 .

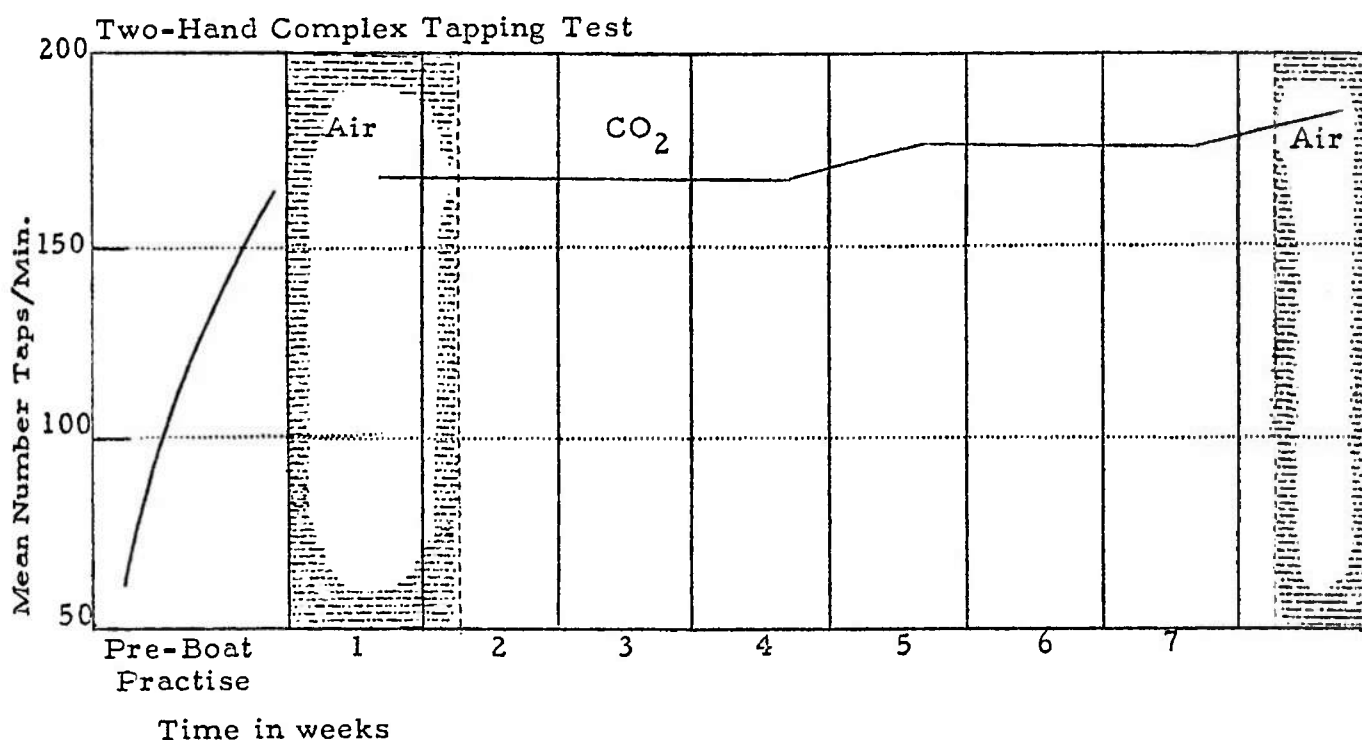


Figure 22.- Two-Hand Complex Tapping Test

3. Problem Solving

a. Addition Test

Purpose: To ascertain if problem-solving behavior as measured by adding random two digit numbers would change under exposure to CO_2 .

Method and Procedure: Ten men were administered mimeographed seventy-five addition problems consisting of three two-digit random numbers. The test was administered in group fashion in the control room of the submarine. The score obtained was the number of correct solutions in four minutes. Incorrect solutions were also measured and presented as error scores. In order to minimize transfer effects between experimental periods four equivalent forms were used non-consecutively.

Results: The results are graphically presented below in terms of the mean number correct solutions for each experimental period. (The medians approximate the means in all experimental periods). The variability about the mean of each experimental period is reasonably symmetrical with some tendency toward positive skewness. ($\sigma = 10$, approximately).

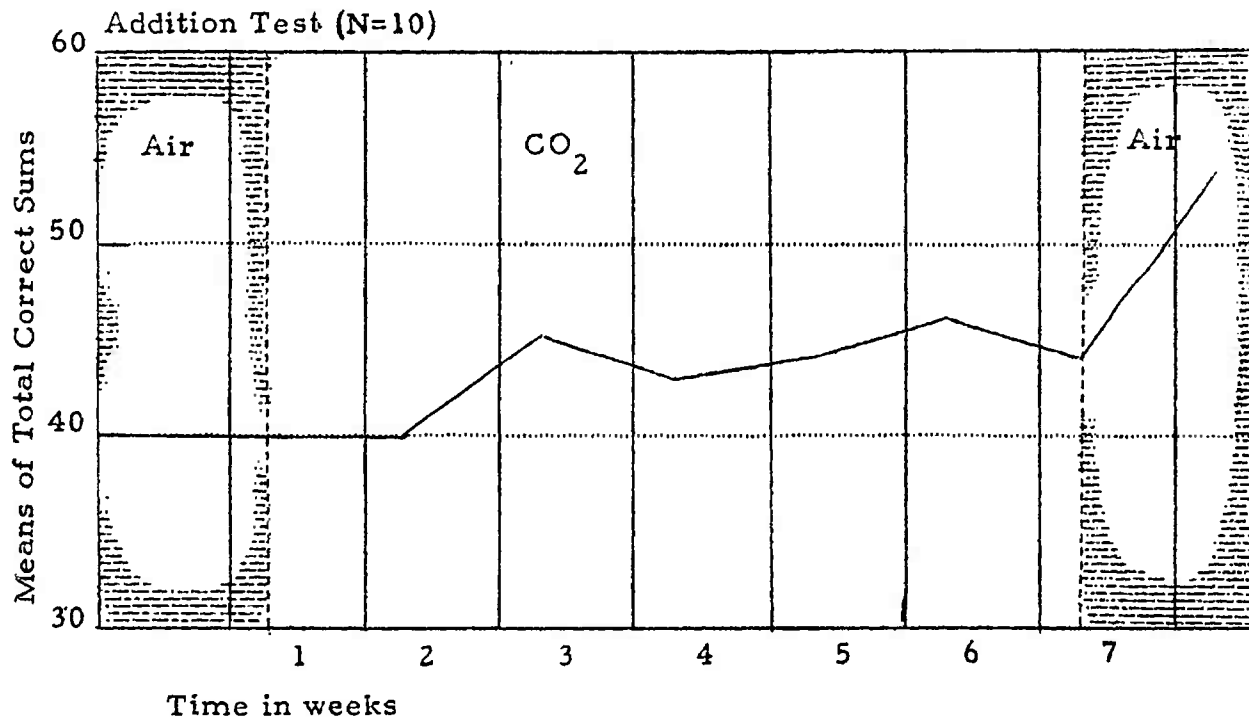


Figure 23.- Addition Test

The mean incorrect solutions are not presented graphically as the mean error scores were reasonably constant for each period at about 3 incorrect solutions.

Discussion: Statements of the significance of the observed behavioral variations in relation to experimental limitations and sources of error are reserved until further analysis of the data has been made.

b. Yerkes Multiple Choice Problem

Purpose: To investigate the effects of the CO₂ confinement on (1) rate of learning multiple choice type problems and (2) the ability to change modes of response as the needs of the situation demands (Rigidity). Another purpose of using this particular apparatus was to make behavioral observations of the subjects involved in a frustrating situation, operationally defined as a situation in which the experimenter has made the problem insoluble.

Apparatus: The apparatus consisted of the Ohio State Modification Yerkes Multiple Choice Apparatus, Stoetling Co.#31265A. A series of twelve levers which could be extended in any number (1 to 12) depending on the complexity of the problem desired. A buzzer was wired in an A.C. circuit in series with a 12 unit contact switch which could be placed on the number corresponding to the correct choice by the experimenter. A screen separated the subject from the experimenter.

Procedure and Method: At the outset of the experiment ten volunteers were used in the Yerkes situation (pre-test control period on air and the first experimental period in the CO₂ conditions. The test was administered individually in one of the officer's staterooms by Weybrew.

Because of lack of information concerning administration time (The Yerkes apparatus arrived at MRL approximately a week before the experiment began) it was found that time was available to test only five subjects since administration time was from one half to three-fourths hour per subject. Five subjects were selected on the basis of "spread" on several assessment predictions, including intelligence and "personality-type" tests. The test procedure was as follows:

Procedure I - Learning and Perseveration (Rigidity) Experiment.

This part of the session was made up of a three choice adaptation problem, concept, middle, left, right or a constant position problem (always eighth, seventh etc. throw regardless of the position of the other alternative choices.) Then a series of 5-choice problems (Problem A.B.C.D.E.) in which the subject learned the concept to criterion which varied

varied from 2 to 5 consecutive correct choices (It was necessary to vary the criterion so that the subject would not learn the exact time when the experimenter changed the concept). The serial positions of the correct concepts were varied so as to minimize memorizing the solutions sequences. After Problem A (e.g. second right) was learned the concept was changed to Problem B (e.g. middle-ness) then C (right) etc. Two scores were obtained viz., (1) Learning score = total trials and total errors to criterion and (2) Perseveration score = number of times the individual persisted in making a previous response after the concept was changed.

Procedure II - Observations in Frustrating Situation

The problem was made unsolvable by varying the correct choices at random. A three alternative situation was used because it "looked" easy to the subject. Several times during the session, the experimenter would ask the subject how many errors he had made, also reminding him that one should attempt to "hit" the correct choice first. Twenty such problems were "set-up" for each subject, the recordings of the observations being made by the experimenter immediately after the experimental period.

Result: The results of the learning study are presented graphically below. The perseveration scores proved to be unreliable because of the subjects attempting to out-guess the experimenter as to when criterion had been reached thus avoiding making perseveration responses. As a result of this procedural error, the data shows an average of 3-4 perseverations for the total session.

Frustration Observations The most obvious generalization from the observations are that all five subjects differed tremendously in frustration tolerance if cursing the apparatus, slamming the throws back, mumbling that "organ" (because of the shape of the Yerkes box, with keys the volunteers at the outset called it the organ problem).

From notations made in each of the experimental sessions in the CO₂ condition it appears that no remarkable changes in behavior in this situation occurred as a function of time in the confinement. One exception did occur, however, in the case of one very intelligent youngster who progressively became more confused in the Yerkes situation as the experiment progressed. A post-test performance half of the Wechsler Bellvue Form II test has been given to this man to compare with a pre-test Wechsler Bellevue Form I to check the hypothesis that some deteriorations had occurred during the experiment.

Discussion: Since only five subjects were tested in all experimental periods any statistical trend indicated by the data is not to be taken as other than hypotheses to check further. A Q-type analysis

(one individual correlated with another) in terms of error, trials, perseveration etc, is underway. Procedural errors and limitations have yet not been completely analyzed.

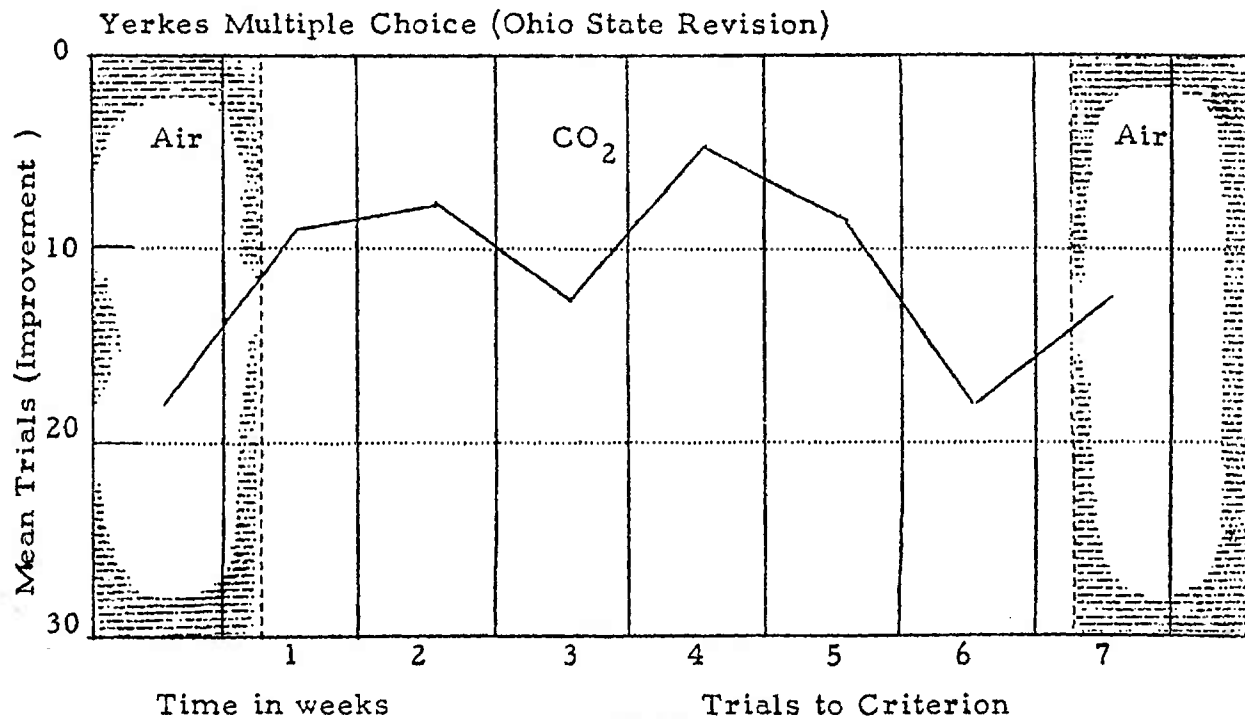


Figure 24.- Yerkes Multiple Choice

----- Trials to Criterion
 - - - Perseveration Score

4. Memory for Letters and Numbers

a. Span of Attention and Immediate Memory

This test was introduced as a measure of "alertness" since it involves apprehension and report of the brief presentation of visual tasks of varying size. The tasks used were five groups of letters and five groups of numbers from three items to eight items in length. Every group of numbers or letters was presented once for 1/5 second and the subject wrote down as many items as they "saw and remembered". All 22 volunteers served as subjects, in groups of five or six each.

Results: The scores for each subject are the totals of correct items, numbers or letters recorded from the three largest number groups and letter groups. Median scores from the 22 subjects are shown in the graph for all nine weekly test sessions. The median number scores lie between 60 and 65 for the entire experimental period. The curve shows no significant rise or fall, and no sudden change of score level. Likewise, the letter span lies between 50 and 60 items with no marked deviations within these limits.

Conclusion: "Alertness" as measured by the span of attention and immediate memory maintained a relatively constant level throughout the experimental period within the submarine.

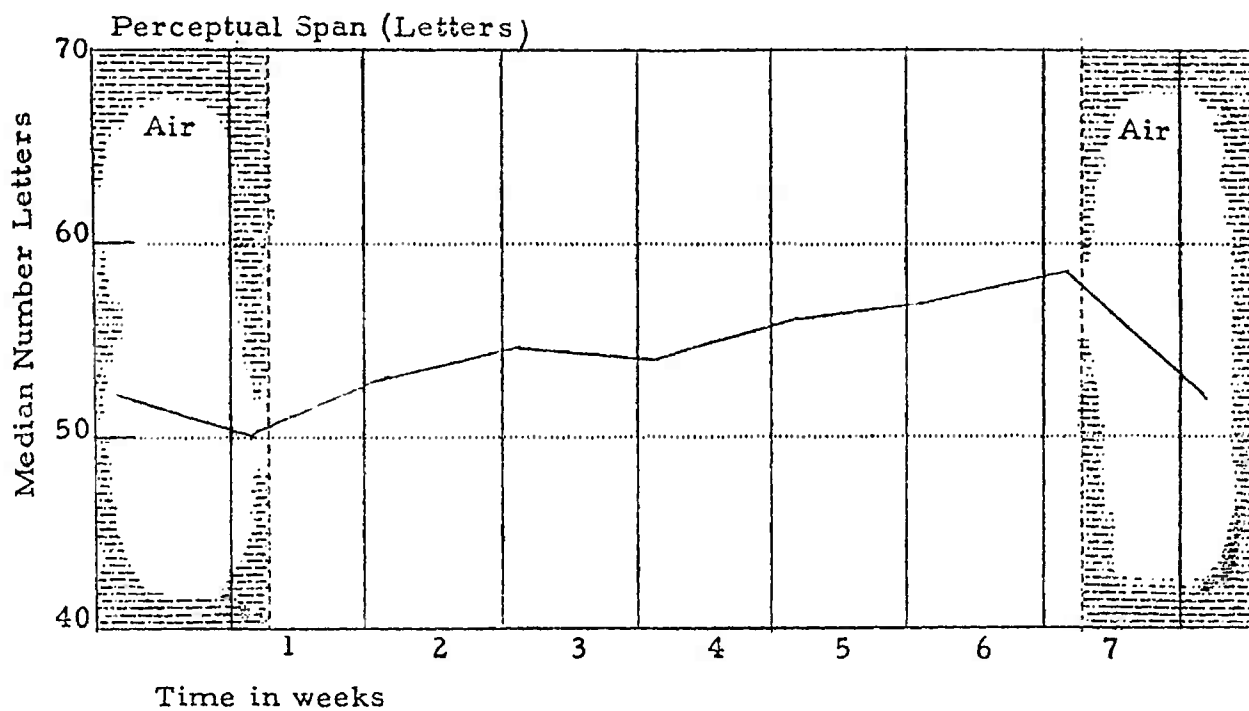


Figure 25.- Perceptual Span Test (Letters)

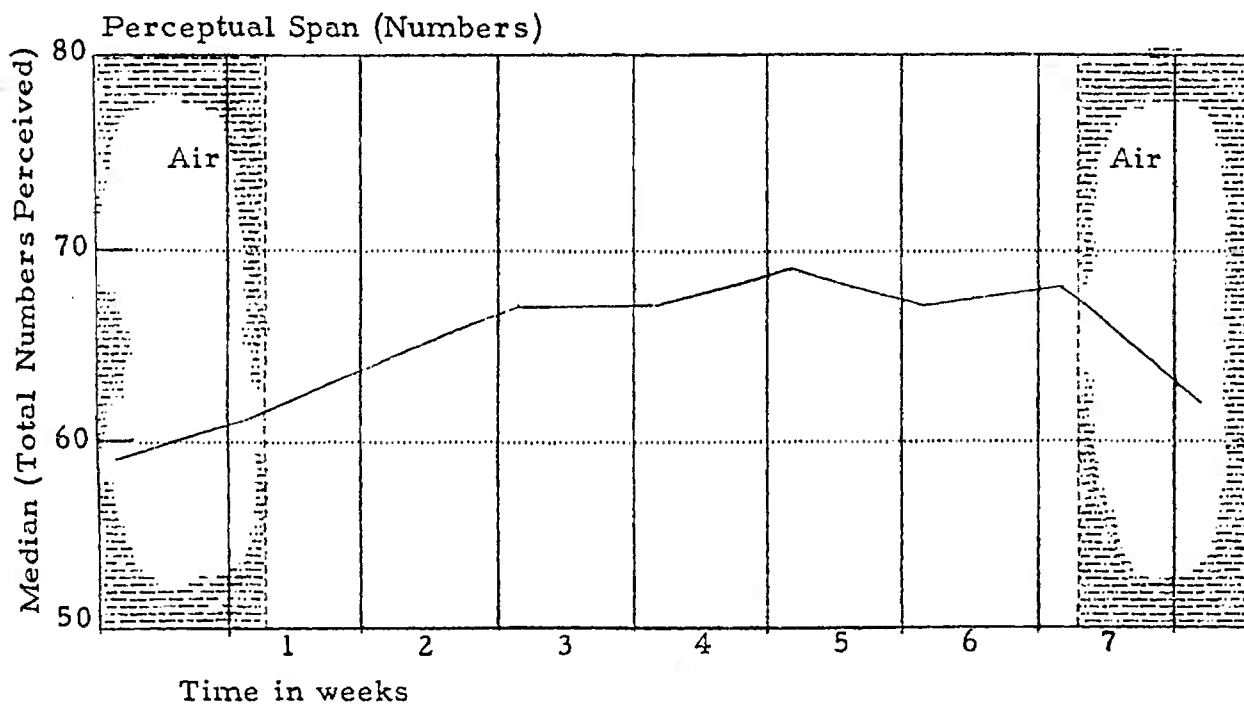


Figure 26.- Perceptual Span Test *Numbers)

5. General Adjustment to the CO₂ Confinement

a. Measurement of Psychological Adjustment

Self Rating Scale

Purpose: To determine what the effects of confinement in the CO₂ conditions would be on motivation, mood, patterning, irritability, etc. We assumed that if optimal rapport was attained and maintained between the experimenters and the subjects, subjective estimates of how an individual "feels" would be useful data for estimates of these psychological dimensions.

Description: The scale consisted of thirteen 5-category rating scales purporting to measure the following adjustment areas (see attached rating scale): Motivation (Items I and VI), Anxiety (Item VIII), Group Interaction (Items V, IX and X), Irritability (Item II), Mood (XI and VII), Quality of Sleep (XII and XIII), Tension (III) and Ability to attend a set task (IV).

The response categories for each dimension were selected by a group discussion of each category, the essential criterion for using the category was that the scale was a uni-directional rank order scale and was made up of as unambiguous categories as possible. The categories were equi-weighted since the variance for each dimension at each administration was reasonably homogeneous.

Procedure: The scale was given bi-weekly on Mondays and Fridays. The subjects were instructed to find a quiet place and check the scale as honestly as possible and return the protocol directly to the examiner so as to minimize the chance of inter-subject comparisons of ratings.

Results: The results for each dimension are presented in terms of Median, Q₁, and Q₃ in the following graphs. It is to be noted that the extreme categories are given for each dimension so as to indicate the direction of the variation; the middle scale categories can be found in the scale included.

(Graphs - Items I - XIII, incl.) (Pgs 49-55)

Preliminary Discussion: Within the limitations that very little is known about the validity of these scales (i.e., the labels given each dimension may or may not be related to what they are actually measuring), the effects of CO₂ and confinement may be indicated by the following trends:

*

See Rating Scale, Pages 57-62.

Motivation: Motivation is maintained optimally by the group up until Monday of week V (4 weeks in CO₂) after which a downward trend ending with the post-measurement in air is noted. It is interesting to note that approximately the same curve is noted in the Hand Dynamometer Perseveration Test (see Figure 20).

Irritability: The group reports showed more irritability after 72 hours in the CO₂ condition as compared with the pre-experimental air data, with a reversion to the pre-test level after 6 days in CO₂. The most irritable period appeared about 30 hours before the post-experimental air was turned in, however, these data may be spurious because of the groups reaction to some administrative barriers to anticipated leave.

Ability to Concentrate: The group as a whole reported greater difficulty in concentrating on the tests, reading, etc. during the first week in the CO₂ conditions. There are no further changes indicative of trends.

Ease of Relaxation: The self-ratings taken 72 hours after the onset of the experimental conditions shows a trend toward the group being able to relax more easily as compared to the data obtained 72 hours before the CO₂ conditions began. Subsequent data shows a slight trend toward more tension as a function of time in the CO₂ conditions.

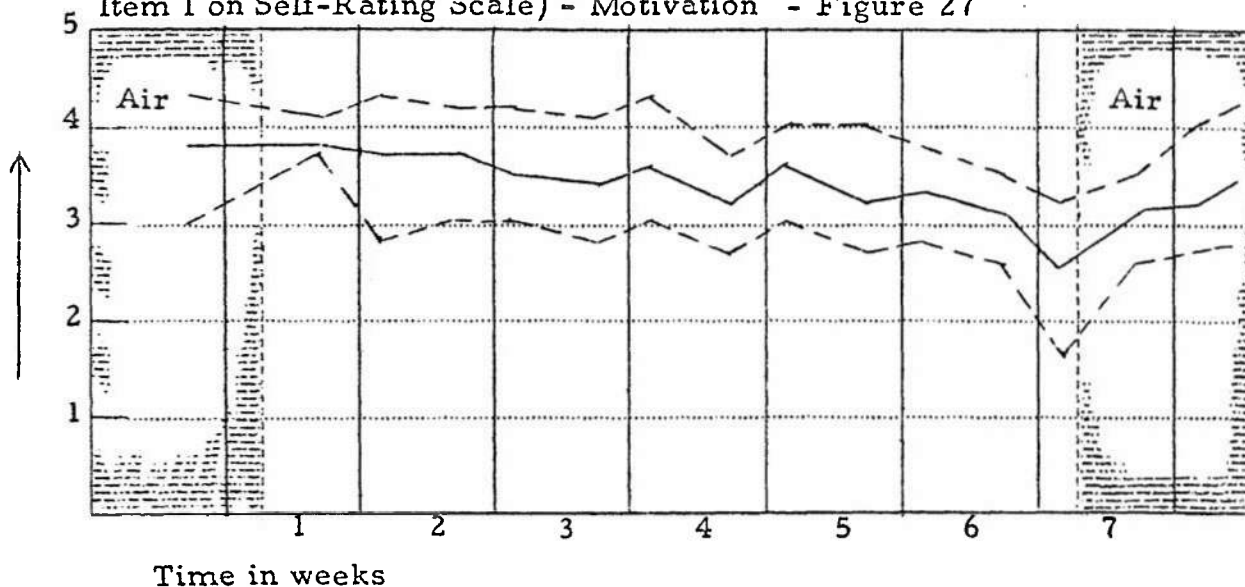
Group Interaction: The group immediately attained and maintained optimal interpersonal rapport throughout the operation, with the possible exception of one or two individuals who experienced mild disharmony in several instances.

General Health and Mood: The data indicates that up until the sixth to eighth day in CO₂ the group as a whole "never felt better", after which a moderate trend toward "feeling unhappy" was evidenced. Since there was an unusually large amount of inter and intra-individual variability in this dimension the trends tend to be masked.

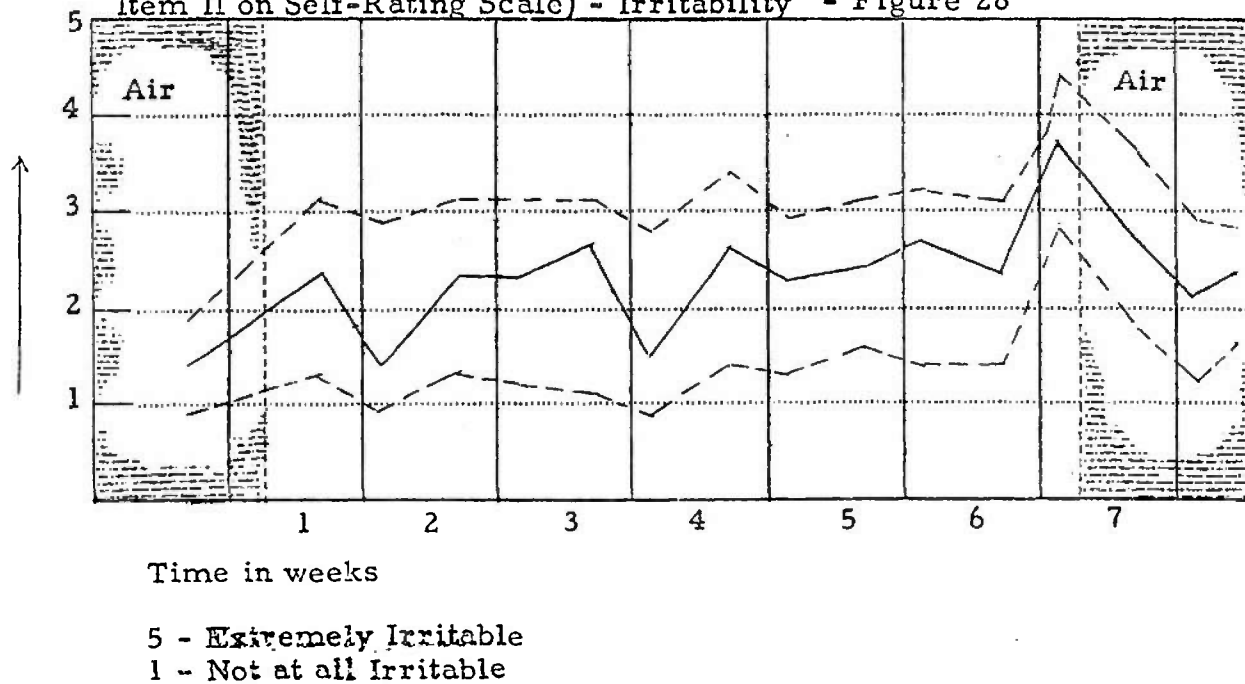
Anxiety: The group reported a benign anxiety at the outset of the experiment. The data indicate dissipation of the anxiety by week 2, and no trends subsequently, except a marked decrease reported 24 hours before disembarkation.

Depth of Sleep: The group reported sleeping less soundly progressively for the first two weeks in the CO₂ conditions. The subsequent measurements show a trend toward improvement of sleep until Monday of week 7, then again the group trend was toward less sound sleep, as reported.

Item I on Self-Rating Scale) - Motivation - Figure 27



Item II on Self-Rating Scale) - Irritability - Figure 28



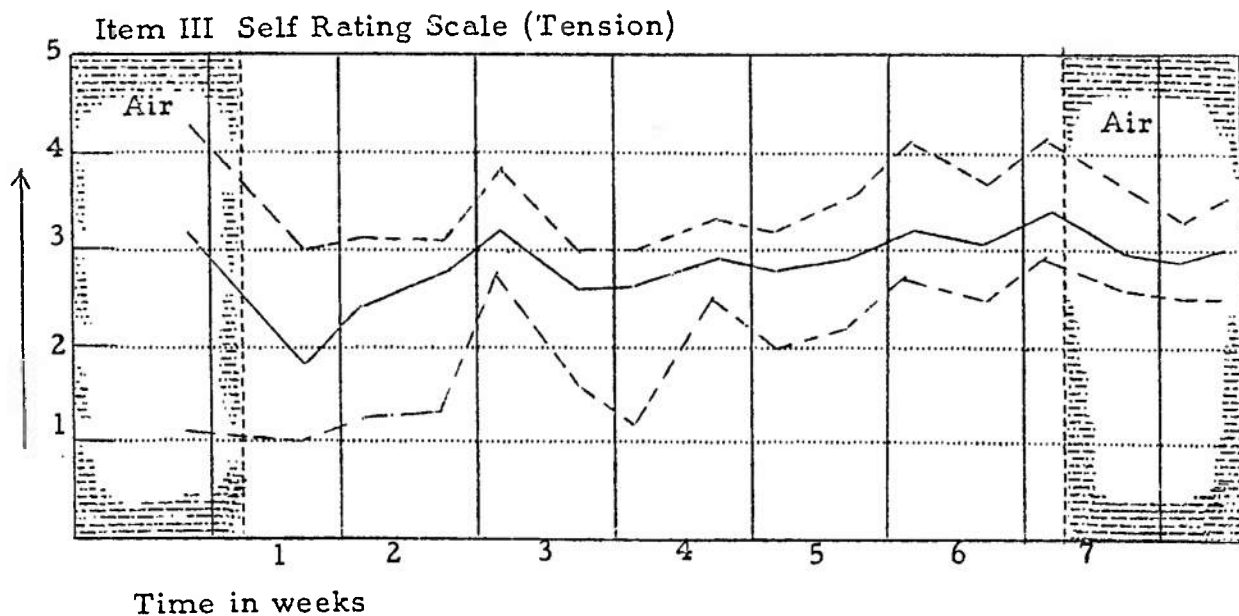


Figure 29.- Self Rating Scale (Tension)

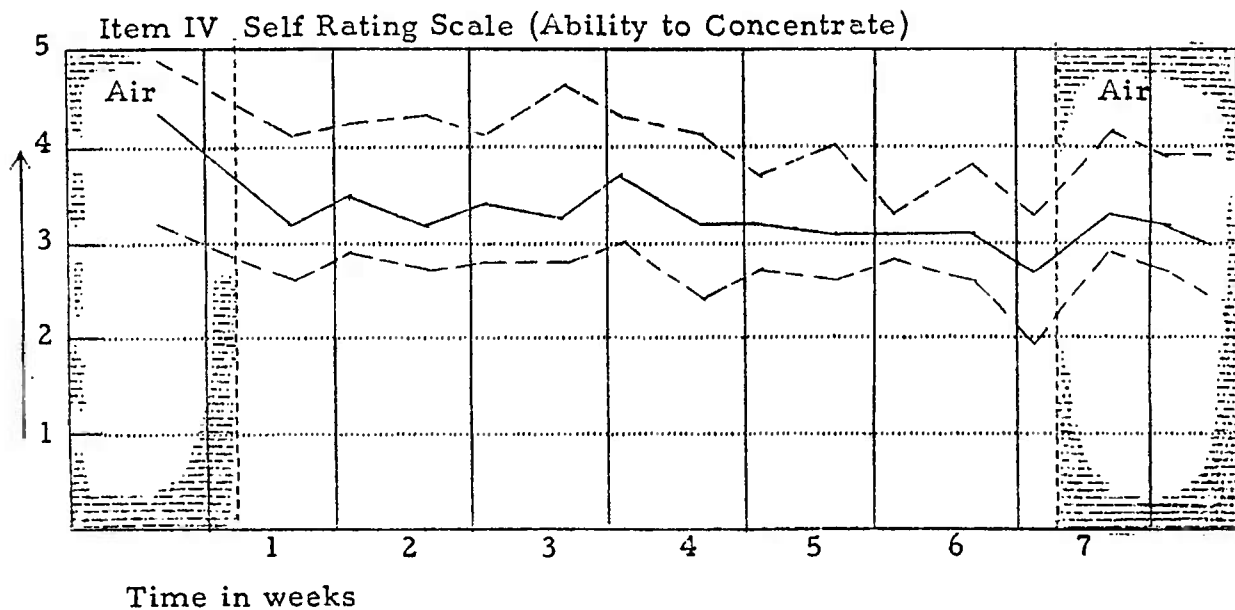
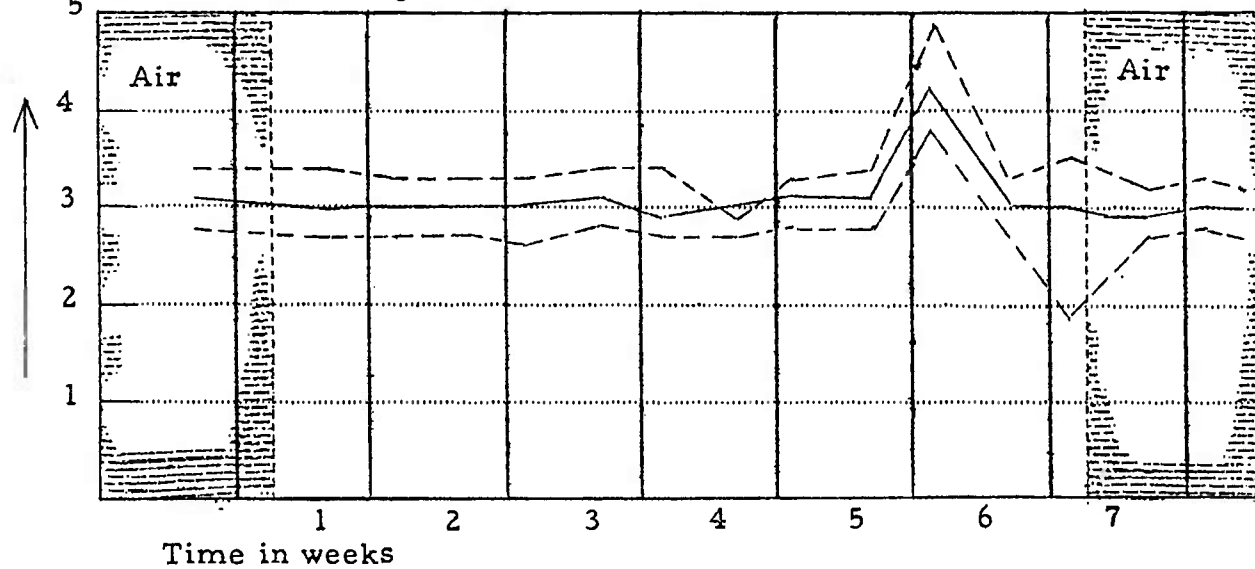
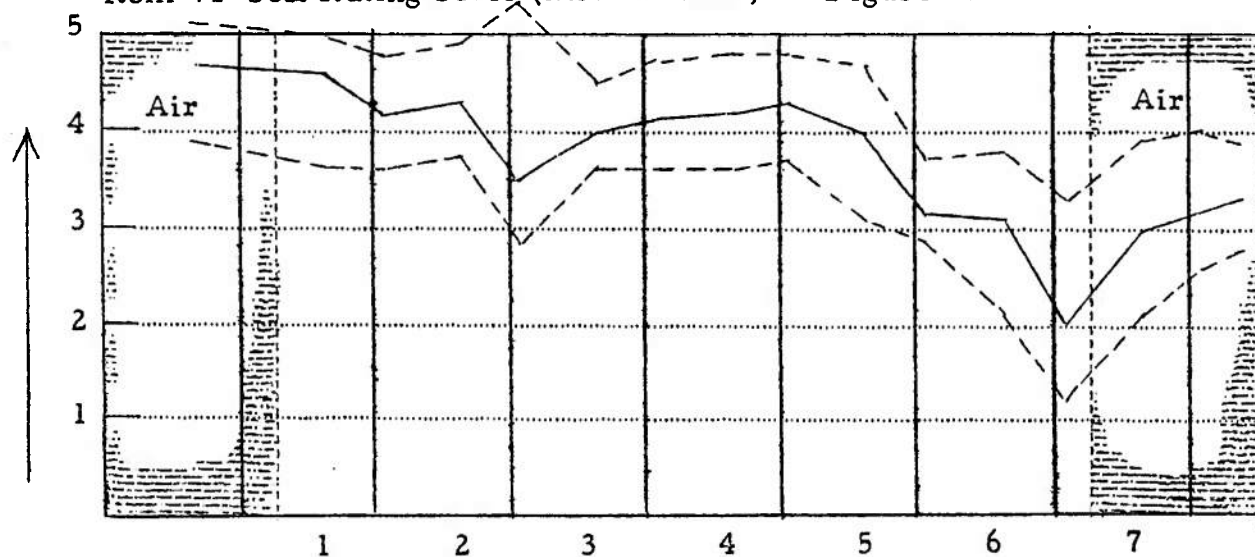


Figure 30. - Self Rating Scale (Ability to Concentrate)

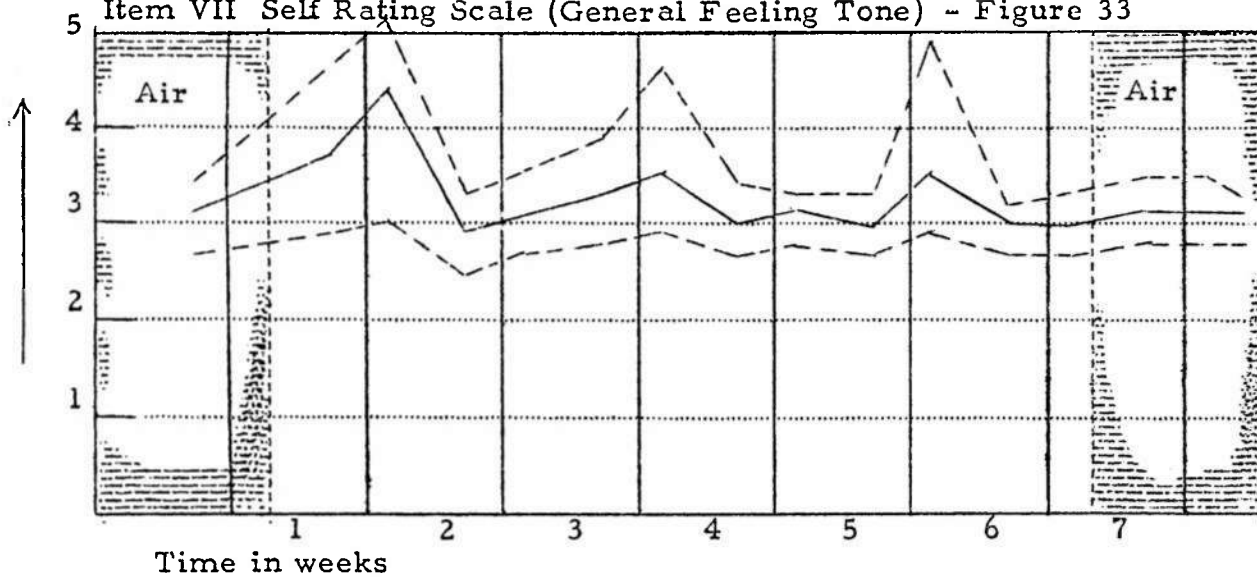
5 Item V Self Rating Scale (Group Interaction I) - Figure 31



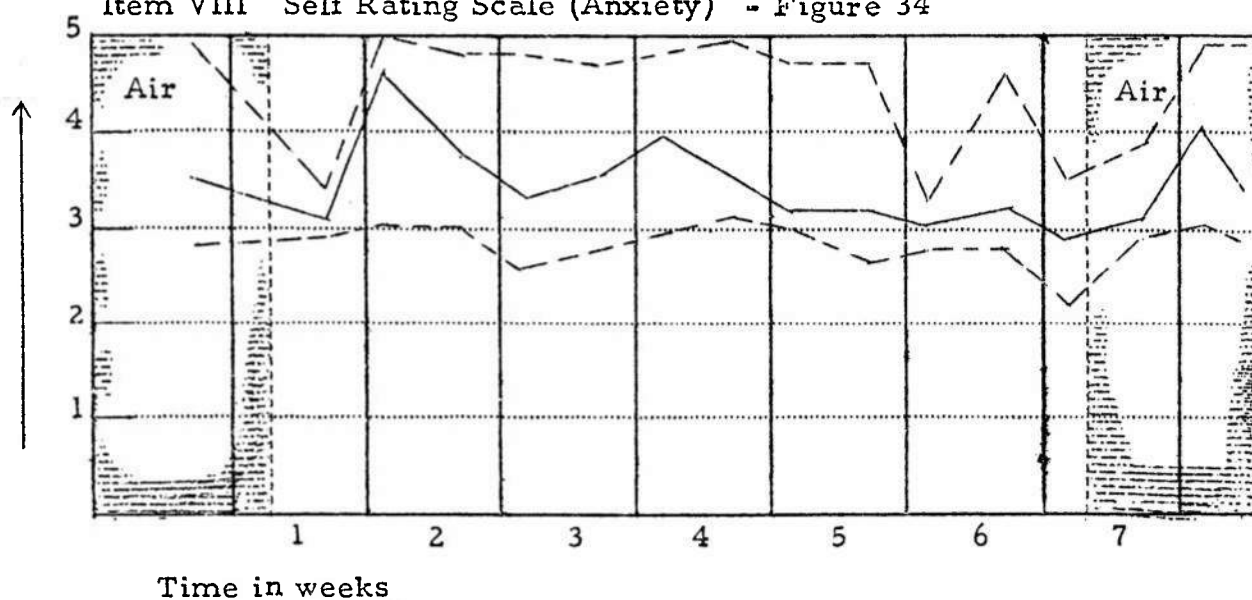
Item VI Self Rating Scale (Motivation II) - Figure 32



Item VII Self Rating Scale (General Feeling Tone) - Figure 33



Item VIII Self Rating Scale (Anxiety) - Figure 34



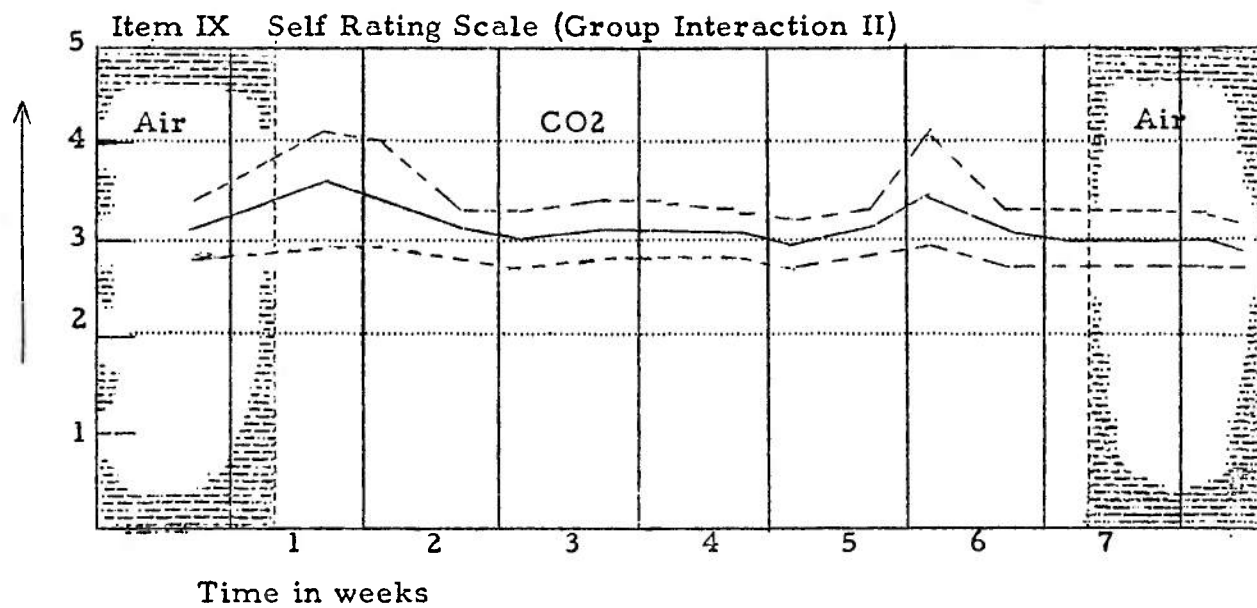


Figure 35.- Self Rating Scale (Group Interaction..II)

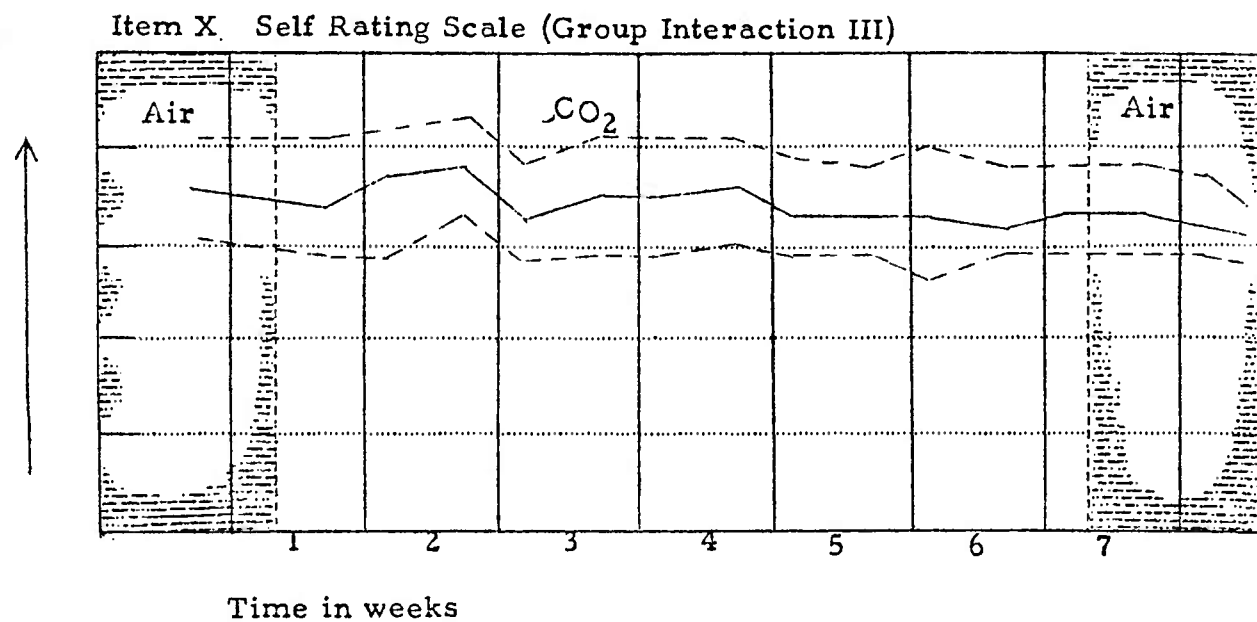


Figure 36.- Self Rating Scale (Group Interaction III)

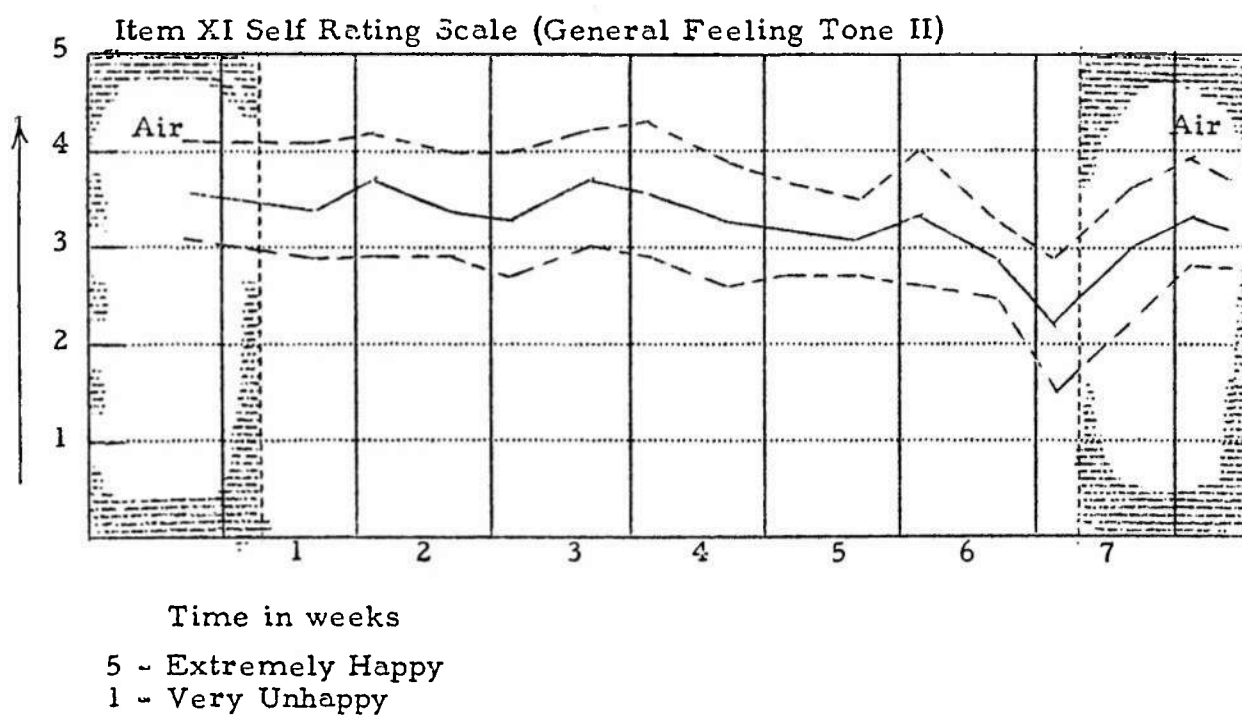
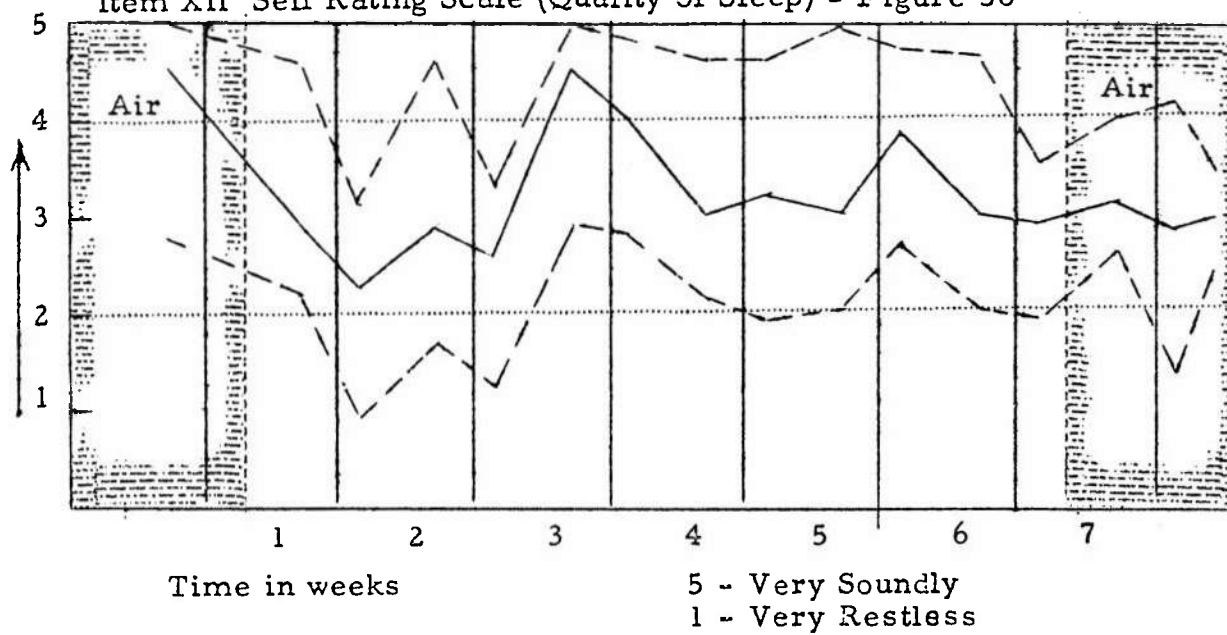
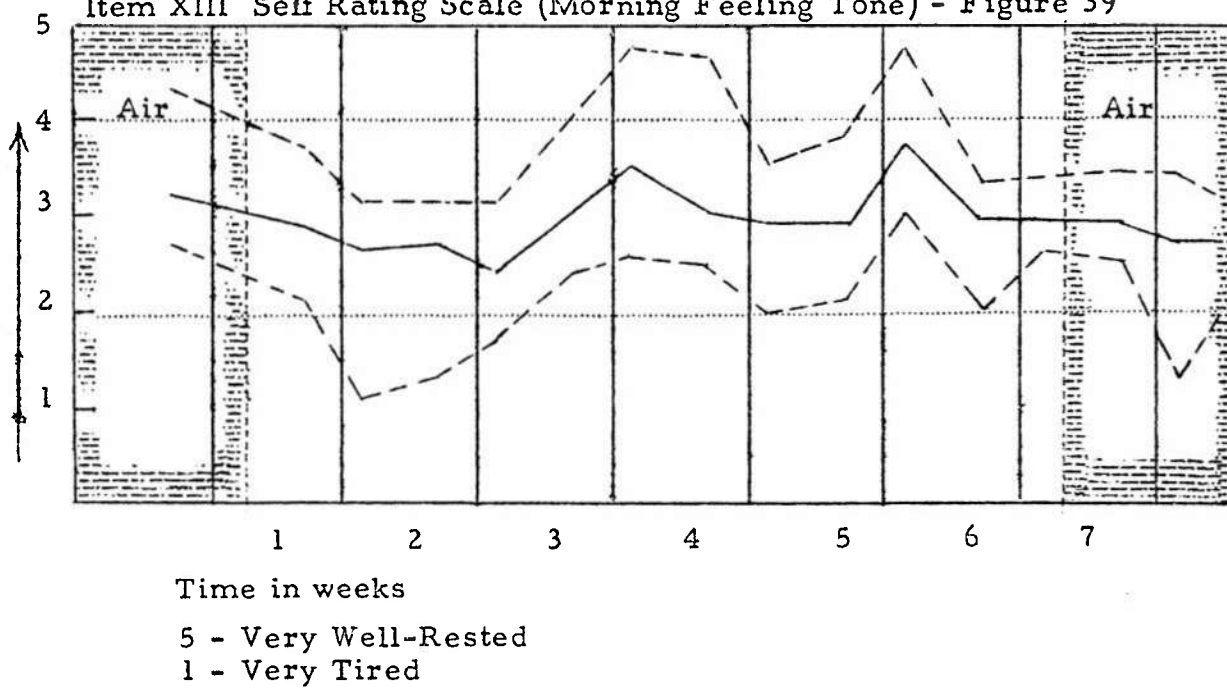


Figure 37. Self Rating Scale (General Feeling Tone II)

Item XII Self Rating Scale (Quality of Sleep) - Figure 38



Item XIII Self Rating Scale (Morning Feeling Tone) - Figure 39



The following is a reproduction of the Self-Rating Scale:

Hideout Number _____
Date _____

SELF RATING SCALE

This is not a test. There is no time limit.
We are simply interested in your feelings
or general impressions of the situation as
you see it. Please do not discuss this with
the other men.

Instructions: There will be a question followed by a series of answers
on a scale. Consider the question thoroughly.
Read all answers carefully and indicate your choice by
making a check () anywhere on the line to describe
the way YOU REALLY FEEL.

Example: Did you find last night's movie enjoyable?

not at all only moderately very extremely
enjoyable slightly enjoyable enjoyable enjoyable
 enjoyable

(If you should check as above, it indicates that the movie
was quite enjoyable, but not extremely so.)

You may also check between the points on the line if you
so desire.

Following each item you will find space in which you are
asked to describe something that happened today which
ILLUSTRATES YOUR FEELING.

We appreciate your cooperation in filling out this sheet as this is a very
important part of the experiment.

I In general, as you look back, how enthusiastic or interested in your task, test or job have you felt TODAY?

very enthusiastic interested moderately interested disinterested bored stiff

Give incidents which will show how you felt:

II How irritable, or easily upset, have you been TODAY?

not at all irritable only slightly irritable as much as usual somewhat irritable extremely irritable

Incidents:

III How easy was it for you to relax TODAY?

very easy to relax somewhat easy to relax easy to relax difficult to relax very tense, couldn't relax at all

Illustrate:

IV How difficult have you found it to concentrate on a task, a test, or job which you were supposed to do today?

hard to concentrate	some difficulty	about the usual amount of effort to concentrate	very little difficulty	no difficulty whatsoever concentrating
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Describe:

V How have you been in conversation with your shipmates today?

very talkative	talking more than usual	as much as usual	talked less than I usually do	hardly talked at all
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Incidents:

VI Judging from the way you have felt today, how satisfied do you feel about the way "Hideout" is going?

Completely satisfied	more satisfied than dissatisfied	about half and half	more dissatisfied than satisfied	completely dissatisfied
-------------------------	--	------------------------	-------------------------------------	----------------------------

Illustrate how you feel:

VII How do you feel your physical health is today?

never felt worse	didn't feel so well today	same as usual	felt better than usual	never felt better
------------------------	---------------------------------	------------------	------------------------------	-------------------------

Describe something that shows how you feel?

VIII To what extent have the day's problems and tasks caused you worry?

very worried	somewhat worried	as much as usual	less than usual	not at all worried
-----------------	---------------------	---------------------	--------------------	-----------------------

Incident to illustrate:

IX How did your shipmates treat you today?

extremely friendly	somewhat friendly	as friendly as usual	less friendly than usual	not at all friendly
-----------------------	----------------------	-------------------------	-----------------------------	------------------------

Describe:

X How did YOU treat your shipmates today?

gave them a hard time all day	heckled occasionally	the usual ups and downs with them	good spirits today
-------------------------------------	-------------------------	---	--------------------------

Incidents:

XI Can you describe the mood you were in today?

very unhappy	somewhat unhappy	neither happy nor unhappy	somewhat happy	extremely happy
-----------------	---------------------	------------------------------	-------------------	--------------------

Describe something to illustrate:

XII How well did you sleep last night?

very soundly	slightly better than usual	about usual	somewhat restless	very restless
-----------------	----------------------------------	----------------	----------------------	------------------

Did you dream, toss, etc.? Describe it:

XIII How did you feel when you woke up this morning?

very well
rested

more rested
than usual

about
usual

more tired
than usual

very
tired

Describe:

6. Personality Dynamics

In order to learn more about the basic personality structure of each individual and for the group as a whole, a series of clinical techniques were selected to add to the data to be collected, which would give a more thorough picture of the dynamic forces operating in the volunteers. The techniques were given in the assessment period for the most part and were given by various members of the Laboratory's Assessment Staff, with the additional assistance of clinical psychologists outside the laboratory.

Knowledge of the personality dynamics of the volunteers is to be used primarily for two specific purposes: (1) to form a base-line upon which the various changes, or lack of changes can be superimposed in order to more accurately account for any behavioral or physiological manifestations which might have occurred, and (2) in order to rule out individual variances which might be attributed to various personality traits within any of the volunteers. These data, when finally processed will then be used to correlate with the physiological aspects of the study. Brief descriptions of the techniques used and the progress in their analysis follows.

a. The Thematic Apperception Test (N-TAT). This is a projective test, designed to elicit personality needs and conflicts affecting the personality of which the individual does not admit, either because he does not wish to, or is not aware of them. Two forms of this test were used in the experiment. The data are being analyzed by Drs. Leonard Eron and Frank Auld, clinical psychologists of the Yale University, School of Medicine, under a collaborative contract.

b. The Rotter Sentence Completion Test. The responses to this test give additional information relative to the satisfactions, annoyances, fears, aversions, likes, interests and satisfactions of the individuals at various times, which are important in the motivation of the personality.

The test was repeated once during the experiment. This aspect is also being analyzed by Eron and Auld under collaborative contract.

c. Rosenzweig Pictorial-Frustration Test. (Navy modification)

This test was selected for inclusion in the battery to measure reactions to frustrations and the direction of aggression which is elicited. Categorically it is possible to represent the types of aggression into three main types: aggression is directed toward the environment, upon the self, or is avoided altogether.

d. Terman Attitude-Interest Test for Masculinity-Femininity.

The manner in which a man views his masculinity and the importance he attaches on it has been shown in previous studies, to be an important factor in how well he gets along in masculine pursuits and in all of his inter-personal relations. Tests have been scored and the range comparing with civilian norms, runs from one individual with a score substantially below that expected of young men of his age and social background, to some which are much higher. On the average the scores were somewhat higher than might be expected. These data will be used in combination with other aspects of the study.

e. Social Attitudes and Public Opinion. It was believed that it would be important to know some of the attitudes which the volunteers subscribed to, for it has been previously demonstrated that such attitudes are highly correlated with other aspects of the personality, especially those at a deeper level. The scales which have had the most extensive use and which substantial norms, including those from military personnel, are those of the Berkeley group*. Their three scales which are reported to measure authoritarianism, radical-conservatism, and anti-democratic trends, were used in the experiment. They have been scored and are being compared with comparable groups of naval personnel, and with other measures, such as intelligence, education, socio-economic background factors and a more generalized mental rigidity.

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* Adorno, et.al. The Authoritarian Personality. (New York: Harper's) 1950

f. The Blacky Pictures. In order to investigate some of the psychosexual factors in the personality, it was decided to use Blum's technique. Norms based on over 2,500 naval personnel were available and a comparison is now being made between the volunteers, a group of naval recruits selected at random, a group of submarine candidates and a group of maladjusted naval recruits. The technique gives not only a total or overall estimation of the personality disturbances, but those in various areas as well.

g. Personality configurations as revealed by the Rorschach Test (LTJG Dennie L. Briggs, MSC, USNR assisted by Herman O. Schmidt, PhD*) Twenty-one of the volunteers were examined by means of the Rorschach test to ascertain certain variables in personality development and functioning which might be pertinent to the experiment. The Rorschach test was selected since it is the most generally accepted instrument in use by students of human behavior for obtaining a cross-section of the structure and dynamics of the individual personality. We could expect to obtain, then, personality data of the individual, as well as of the group, which will be utilized for:

(1) Assessment and selection of candidates.

(a) To detect and eliminate from the experiment any candidate who, on initial testing, gave evidence of any behavioral pathology which might be aggravated during the experiment, or which might bias the findings.

(b) To re-evaluate the personality structure by retesting upon completion of the experiment, in order to ascertain and record any changes that might have occurred in the personality structure.

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* Chief Clinical Psychologist, Norwich State Hospital. Rorschachs were scored and report written while Col. Schmidt, USAF, was on training duty at the U. S. Naval Medical Research Laboratory, New London, Conn. Appreciation is expressed to cognizant officials in the U.S. Air Force and the U. S. Navy for making this possible.

(2) Description of personality structure.

(a) How do these men, as a group, compare with others-- that is, "normal" civilian adults? (Note: Norms based on a similar Navy population were not available, hence it was necessary to use Beck's "normal" sample for comparison.) Are there any significant differences? And, if so, in what areas do they occur?

(b) As a "base line" for comparison of temporary or more fundamental subsequent behavioral changes that might develop.

(3) Comparison of psychological and physiological data.

(a) Predictability to withstand the experimental situation.

(b) Relation of various Rorschach variables to physiological concomitants. (For example: Basic anxiety to pH of the blood.)

Presentation of these preliminary findings* from the Rorschach centers around two main areas: A comparison of the candidates with Beck's "normal" sample, and comparison of the candidates' protocols, as a group, before and after the experiment. A separate more complete report dealing with the other aspects of the Rorschach experiment is in preparation.

(1) The volunteers and Beck's Sample. In comparing these two groups for test items that appeared to be the most divergent, we see that the volunteers gave a greater number of responses, but also attended more to picayune and inconsequential, while at the same time finding more relationships in the disparate elements of the blots. In the areas depicting affective energy, we find the volunteers revealing a greater quantity. This is particularly striking where affect is measured as dysphoria. In their perception we find the volunteers less accurate than Beck's normal subjects, but nevertheless within healthy limits. Again, there is a somewhat lessened adaptability of their thinking to group standards. In the test factor which can be taken as a measure of self-will, we note the volunteers have a more substantial quantity.

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* From a very preliminary inspection of the Rorschach protocols. These are, of course, tentative and must await further more intensive analysis of the data.

In brief, these differences might appear to be generally accounted for in the lower mean age of the volunteers, i.e., the volunteers were still maturing. The one outstanding inconsistency in this is the greater influence the dysphoric stimuli had for the volunteers. Since this is quite generally linked with anxiety, it seems reasonable to attribute this to a real kind of anxiety felt by these volunteers who were about to enter, as subjects, upon an experiment which was not quite comprehensible to them. Their very natural fears as to what might happen to them had full range.

(2) The experiment: Before and after operation Hideout. Combining the data of the group before and after the experiment reveals certain changes that occurred. The productivity diminished, and there was a shift of attention from the minute elements of the blots to the larger areas. As these men thus became more concrete and practical, there was a lesser tendency to connect disparate elements. In the affective sphere, there appeared less responsivity. Most striking, again, was the shift in the dysphoric stimuli, the mean falling off not only below the volunteers' previous mean, but significantly below Beck's normals' mean. There was some slight increase, perhaps not statistically significant, however, in the accuracy of the perception and in conformity to group thinking. What appears to have occurred is this: Before the experiment the volunteers were anxious, and in their attendant feelings of insecurity, over-produced as a "cover-up" for the anxiety; following termination of the experiment, the volunteers apparently no longer were anxious and no longer felt a need to "do well" either as a "cover-up" or as a means of insuring their selection for the experiment.

7. Summation of Psychological Aspects

In general, there were no seriously deteriorative changes in the behavior of the group in sensory, psychomotor, affective or other psychological areas. There are, however, indications of trends which should not be interpreted other than as hypotheses which are to be investigated by a more complete analysis of the data at hand or by future experimentation with more controlled conditions.

Sensory and Perceptual Processes:

- a. Vision: The data indicate negligible differences in acuity, accommodation, and scotopic adaptation with some moderate trend toward esophoria, as measured.
- b. Audition: Results indicate insignificant changes in ability to discern frequency differences in the region of 1000 cps. Measurements of auditory acuity are contaminated by the masking effect of ambient mechanical noises, hence it is not practicable to speak of effects of prolonged exposure to CO₂ upon hearing sensitivity.

Psychomotor Efficiency:

- a. Manual Dexterity (stereotyped rapid movements) The data indicate a significant increase in speed of movements in the first CO₂ experimental measurements. This improvement is lost in the second week in CO₂ period. The remaining data show only a very slight trend toward improvement with no reversions. (The operations used to define this dimension were Minnesota Manual Dexterity Test and Letter Cancellation.)

- b. Psychomotor Performance Demanding Perceptual and Spatial Ability:

As measured by the Location and Copying sub-test of the McQuarrie Test of Mechanical Ability, there is some indication that performance is slightly less efficient in the first week in CO₂, with recovery in the second week in CO₂. The tracing test shows progressive deterioration up to the third week in CO₂ followed by a slight trend toward improvement in the remaining experimental periods.

- c. Steadiness: There is a significant decrease in hand tremor in the first CO₂ period as compared with the pre-experimental control data. In the second CO₂ measurement this data shows a reversion to the pre-test level. The subsequent measurement shows no indication of trends in either direction.

- d. Body Sway: The first measurement in the CO₂ conditions shows significantly less body sway as compared with the pre-test data taken in air; however, the post-test measurement in air did not show any loss of equilibrium as compared with the measurement in the CO₂ condition.
- e. Aiming: There was slight indication that aiming accuracy, as measured, is somewhat less as compared with the pre-CO₂ control data. There was minimal variation after the second week in the CO₂ situation, and no further trends were observed.
- f. Strength: There is some slight indication that strength, as measured by maximum hand dynamometer readings, is slightly depreciated in the CO₂ conditions; however, the fifth week measurement in CO₂ was the highest of all experimental periods, with the sixth week being the lowest. That results, if any, are spurious cannot be determined without further analysis of the data.
- g. Complex Coordination: Twenty-one practiced subjects, measured weekly in the CO₂ condition, showed no significant deviation from the negative accelerated learning curve in the air measurement as compared to measurement in the CO₂ condition. The general impression is that bilateral coordination was not affected by the CO₂ condition; however, a control group design is necessary to investigate this hypothesis.

Problem Solving:

- a. Addition: In solving addition problems, data from ten subjects measured weekly showed minimal inter-period variation with the exception of a significant improvement comparing the post-CO₂ control measurement with the last measurement in the CO₂ condition.
- b. Yerkes Problem Solving: Learning scores and perseveration in making inappropriate responses showed no significant change, with the exception of one subject who showed progressive deterioration in the experimental situation.

Memory for Letters and Numbers - Perceptual Span: (The assumption is made that this test measured behavior related to some attention or alertness factor.)

A moderate drop occurred in the first CO₂ measure-

ment with a reversion in the second CO₂ period in perceptual span for letters. Minimal variation is observed in the data obtained in the following periods. No significant change occurred in the perceptual span for numbers.

General Adjustment to the CO₂ Confinement:

Based on the twenty-two men's responses on the self-rating scale, the analyses of the responses show motivation declined slightly during the experiment, tension increased slightly, anxiety moderated but was high throughout, some slight interference in attention was experienced early in the experiment, sleeping habits were interfered with at the outset but improved, and some evidence of a benign malaise occurred in the group early in the CO₂ situation.

The Assessment Battery: The complete list of tests administered in the assessment battery are presented below:

- a. Sensation and Perception Studies
 - 1. * Amplitude of Accommodation (Phorometer, trial lenses)
 - 2. * Bausch and Lomb Ortho-Rater Phoria measurement
 - 3. " " " Depth perception
 - 4. " " " Visual acuity
 - 5. " " Stereo Trainer (Stereoptic acuity)
- b. Motor Performance Studies
 - 1. Breath holding
 - 2. * Hand Dynamometer
 - 3. * Minnesota Manual Dexterity
 - 4. Heinrich Two-Hand Coordinator
 - 5. * Two-Hand Complex Tapping Board
- c. Thought Process Studies
 - 1. Wechsler-Bellevue (Verbal and Perceptual Intelligence)
 - 2. Card Sorting (Mental Rigidity)
 - 3. Revised Beta (Non-verbal Intelligence)
- d. Psychiatric Studies
 - 1. Personal History (Background data)
 - 2. Cornell Index (Psychiatric Screening data)
 - 3. Individual Psychiatric Interview
- e. Clinical Psychology Studies
 - 1. Photo preference (group empathy)
 - 2. Rorschach Ink Blot (Psychodynamics) (Before and after Experiment)

* Administered both in the Assessment Battery and during the experimental period.

3. Thematic Apperception Test (Personality Dynamics)
4. " " Test-X (Personality Dynamics)
5. Incomplete Sentence Test (Personality Dynamics)
6. Causes and Consequences Test (Empathy)
7. Public Opinion
8. Picture Frustration Test (Frustration-Aggression)
9. Terman Attitude-Interest Test (Masculinity-Femininity)
10. Blacky Test (Psycho-sexual development)
11. ** Relational Analysis (Tagiuri)
12. ** Davis Personal Problems Test

Progress of the Assessment Analysis

a. Predictor-Criterion Matrix Analysis

All of the assessment data except the clinical-type data has been entered in an R-type matrix (29x29) and are being correlated with the some 12-16 Adjustment Rating Criteria obtained during the Operation. A Q-type analysis comparing every individual's test battery pattern with every other person's test scores, is also underway.

b. Description of the Hideout Group in Terms of Intelligence Test Scores and Navy Battery Scores

The Wechsler Bellevue Full Scale IQ's of the group ranged from 88-132, Median 113.5; the Beta IQ's ranged from 86 to 123, Median 111.7; the GCT scores ranged from 32 to 68, Median 50.5; and the Combined GCT and Ari scores of the group ranged from 64-136 with a median of 99.5.

c. Analysis of the Clinical Assessment Battery

The analysis of some of the projective-type data making up the battery is well underway. Normative data for the Navy TAT is being compiled for comparison with the TAT data obtained from Operation Hideout.

** Given only in the experimental period

D. Interpersonal Relations

In exploring the various psychological aspects considered to be important under operating conditions such as those imposed by incarceration together with prolonged exposure to an increased concentration of carbon dioxide, it was believed that how a man views other people and situations in his immediate environment would be extremely crucial. Further, the interpersonal relationships formed and the group relationships as well were believed to form a vital aspect of over-all functioning from a physiological standpoint as well. As the experiment progressed these notions became strikingly evident and are now being formulated as definite hypotheses which may be further refined and tested at a later date.

Provisions had been made for collecting qualitative data by interviews and with Bales' "Interaction Process Analysis" technique^(), to measure various aspects of interpersonal relationships. Because of time limitations, it was not possible to use Bales' technique. Dr. Dembo of Clark University, was contacted early in the planning of the experiment and suggested several possible areas of exploration. At her suggestion, photographs were taken of all the candidates early in the assessment process, before the candidates knew one another well. These were utilized for several purposes during the experiment.

Resulting from a visit by Dr. Joan Criswell, of the Office of Naval Research, to the Laboratory, a coordination of efforts between the staff and Doctors Bruner and Tagiuri of Harvard's Laboratory of Social Relations was established. Arrangements were made to add several quantitative techniques to the experiment which Bruner and Tagiuri had developed under contract with the Office of Naval Research.

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() Bales, R. F., Interaction Process Analysis: A Method for the Study of Small Groups (Cambridge: Addison Wesley, 1951).

These data are now being processed collaboratively and thus serve to give further empirical validation to some of the theoretical models which they have developed^() as well as to formalize various aspects of the data concerning interpersonal relations for operation Hideout.

While results are not yet available, brief descriptions of the various techniques chosen will be presented here.

1. Relational Analysis (RA) This is a method whereby relationships between all possible pairs of individuals in a group are mapped out in terms of their mutual feelings and their perceptions of these feelings. This technique has been intensively explored and it has reached a stage where it can be applied.

a. "Salzburg" Relational Analysis (SRA) With the Salzburg type of Relational Analysis, in addition to the type of information described above, data were obtained on the volunteers' conception of the relationships existing in the group. Since the relationships are known from straight sociometric aspects of this technique, the members' concepts of the relationships within the group can be examined for the degree to which they correspond to reality.

b. Preference Ratings (PR) Another means by which we attempted to obtain measurements of the relationships between the subjects was to have each man arrange the other men in terms of the degree to which he preferred them. This was done by supplying the volunteers with a deck of photographs of all the other men and asking them to arrange them on a continuum of best to least liked. We thus obtained a preference rank for each volunteer and when the mean preference rank given by all the others is computed it will indicate the position of each man in the favor of the group.

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() Annual Technical Reports 1 and 2, ONR contract N5 ori 0746, Office of Naval Research and Laboratory of Social Relations, Harvard University, 1952-53.

In a second step, by asking the volunteers to indicate what preference rank they thought they would receive from each of the other men, we obtained data on the volunteer's estimate of his own position in the favor of the group. We can thus compare the position of each man in the group with his estimated position.

2. Photo Interpretation. Early in the assessment process each candidate was interviewed and asked to give a character sketch of each of the other men, from their photographs. These were recorded and have been transcribed. They were then asked to pick out those individuals they thought they would like and those they would not care for, solely on the basis of their photograph. This process was then repeated after the experiment had been in progress for approximately five weeks. At this time the volunteers knew one another intimately.

The typescripts of the character sketches are being read and the characteristics each man gives are being transferred to 3x5" cards. The traits a man uses are then counted and judged as to whether they are positive or negative qualities. The cards are then being arranged for the group as a whole.

From these data information can be tabulated to show (a) how a man perceives others, and (b) what are the characteristics a person uses to evaluate others (both the number he uses and the kind). From this information it will be possible to ascertain what a given individual wants, and what the men want as a group.

3. Further use of the Interpersonal Data. The data obtained by these methods can be used in two ways: First, the nature of the relationships formed by the volunteers can be used to supplement information in relation to other aspects of the experiment; and second, the data can be integrated with the rest of the psychological and psychiatric studies, thus serving the function of making clearer the connection between personality variables and interpersonal relations.

E. Trace Substances

Analysis for trace elements (arsine, stibine, acrolein and aldehydes) were performed by Cdr. C. P. Yaglow, USNR and were entirely negative. The effect of carbon monoxide as a habitability factor is the subject of a separate report, MRL 223, (SECRET).

F. Dental Aspects

The dental research facility at the U. S. Naval Training Center, Great Lakes, Illinois, made lactobacillae and streptococcus saliva counts of the men on Operation Hideout. Contrary to expectations, there was no increase in the number of organisms in the saliva. This may have been due to the nutritional habits of the man. Lieutenant C. H. Tiberi, DC, USN, of the base dental dispensary made color photographs of the mouth of all participants of Operation Hideout for a careful study of physical changes in the teeth, gums and oral mucosa. These pictures gave inconclusive results, partly due to technical accident in the development procedure.

CONCLUSIONS

1. Twenty-three human volunteers were placed in a partially activated fleet type submarine for a period of two months to determine the effects of prolonged exposure to 1.5 per cent carbon dioxide.
2. Prior to being placed on board the submarine they were given an exhaustive physical, psychological and psychiatric assessment.
3. The first nine days on board was a control period during which outside air was circulated through the submarine. This was followed by exposure to 1.5 per cent CO₂ for a period of forty-two days, which was in turn followed by a second control period of nine days.
4. During the period of exposure the concentration of CO₂ in the air was maintained at a level of 1.4 - 1.6 per cent. The oxygen concentration was maintained at 20.5 per cent.
5. Following their release from the submarine, and after a ten day rest period, the volunteers were again studied in the laboratory.
6. No changes in the basal pulse rate, weight, oral temperature, or blood pressure were observed during the exposure period.
7. Measurement of the diurnal variations of blood pressure, pulse rate, oral temperature and total leucocytes revealed no consistent change in the diurnal cycles.
8. The alveolar CO₂ tension was elevated approximately 8 per cent above control values during the exposure period.
9. Pulmonary ventilation was also increased approximately 8 per cent during the exposure period and returned to the initial level within the first three days following the exposure period.

Conclusions (continued)

10. The oxygen consumption appeared to be somewhat increased during the first part of the exposure period and then later returned to the initial level.

11. The pulmonary CO_2 excretion showed a cyclic variation during the exposure period, being decreased during the first week, increased during the second, third and fourth weeks, and decreased again during the fifth and sixth weeks.

12. The ventilatory response to inhalations of higher concentrations of CO_2 (5%) was found to be decreased as compared to the control level during the sixth week of exposure, indicating a decrease in sensitivity to CO_2 . It was further found that this ventilatory response to higher concentrations of CO_2 did not completely return to the initial level as long as four weeks following the exposure period.

13. Hematological studies revealed that prolonged exposure to 1.5 per cent CO_2 does not seem to influence the erythropoietic system.

14. The leucopoietic system, however, seems to be affected more, as shown in a consistent decrease of the total neutrophils throughout exposure to CO_2 and eight days following exposure.

15. Throughout the exposure period the eosinophil count showed a consistent downward trend. This trend persisted for eight days following the exposure period, indicating an increasing stress on the adrenal system.

16. Electroencephalograms made during sleep indicated that the depth of sleep was reduced during the exposure period.

17. The excitability of the visual pathways, as measured by the flicker fusion frequency, showed no change during the exposure period.

18. The changes which appeared in the electrolyte composition of the serum were small and consistent with a very mild respiratory acidosis.

19. The electrolyte composition of the urine showed no appreciable change during the experimental period. However, until intake figures have been collated no conclusions on electrolyte balance can be drawn.

20. Urine bicarbonate remained within the control range for the first two weeks of exposure. Following this it began to rise, reaching a peak near the end of the fourth week. There was a brief fall to control levels at the end of the fifth week. Immediately following the return to outside air there was a sharp rise in excretion which returned to normal at the end of five days.

21. From the psychiatric point of view it can be concluded that (a) no major psychiatric problems were encountered; (b) moderate increases in anxiety occurred at times and were usually directly associated with and proportional to the situational factors involved, and (c) individual performance during the Operation roughly correlated with the pre-experimental psychiatric assessment.

22. A study of the sensory and perceptual processes indicates that no significant changes occurred during the exposure period.

23. Studies of psychomotor efficiency as measured by a large battery of tests failed to reveal any decrement in psychomotor performance as a result of exposure to the concentration of carbon dioxide employed in this experiment.

24. Problem solving abilities as measured by an addition test and the Yerkes Multiple Choice test failed to show any marked decrement of these abilities.

25. The span of attention and immediate memory remained relatively constant throughout the experimental period.

26. A report of the measurement of psychological adjustment is included in the report, but no statement of summary can be made.

27. An analysis of the submarine air for trace elements was performed during the third week of the exposure period and found to be essentially negative. A separate report on this subject, however, has been submitted.

28. A study of the bacterial content of the saliva revealed no change during the experimental period.